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COMPREHENSIVE PLANNING FOR AIR QUALITY CONTROL

January,1978

Final Report

U.S. Environmental Protection Agency
Region VIII

Air and Hazardous Materials Division
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This report is intended for use by planning agencies, regulatory organizations and elected officials in approaching in a systematic way methods to analyze, control, and plan for air quality. The report documents the relationship of air pollution to the performance of city systems. It outlines a methodolody for evaluating the air pollution impacts of growth and development, and it provides a framework for incorporati~~on~~ng air quality as a criterion in the comprehensive planning process.

Air pollution topics are discussed in the report according to the following format:

Chapter I: Health and welfare impacts of air pollution; legal and regulatory framework for air quality planning
Chapter II: Methodology for integrating air quality criteria in the comprehensive planning process
Chapter III: Description in greater detail of analysis and evaluation techniques that are appropriate for considering air quality impacts of regional development
Chapter IV: Consideration of specific air quality strategies in relation to planning and public investment decisions.
Chapter V and VI: Consideration in greater detail of social and economic issues associated with air quality control
Chapter VII: Conclusion

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PIKES PEAK AREA COUNCIL OF GOVERNMENTS

PPACG

27 EAST VERMIJO
COLORADO SPRINGS, COLORADO 80903
PHONE (303)471-7080

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COMPREHENSIVE PLANNING FOR AIR QUALITY CONTROL

Prepared by

Pikes Peak Area Council of Governments

Report Author: Julian Beaver

EPA CONTRACT No. 68-01-4178

Project Officers: David Kircher
Martha Burke

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FOREWORD

This report is intended to be of use to planning agencies, regulatory organizations, and elected officials in approaching in a systematic way methods to analyze, control, and plan for air quality. A proper style is difficult to achieve in such an endeavor. Elected officials, at least some of them, still want to know why we need planning and feel that most planners are a kind of bureaucratic trumpet propelled by hot air and good intentions. The regulatory agencies have long since recognized the need for controlling the environment and are impatient with the wavering steps of local communities to get about the business at hand. Other planning agencies want the kind of technical information that will allow them to analyze air pollution problems in a timely and cost efficient manner. A report aimed at all of these actors may consequently appear naive to one, obtuse to another, and plodding to a third. The authors, therefore, apologize at the outset for these unfortunate consequences and will rely on the good judgement of the reader in being able to cut through the parts that are superfluous to him and to focus on the matters that are of most importance.

For those who are least familiar or most confused with air quality issues, Appendix A is included as a glossary of acronyms, terms, and concepts that apply to air quality planning. This glossary defines terms not otherwise identified in this report and includes additional terms one is likely to encounter in related readings. A brief review of the glossary might be the first step in reading this report, therefore.

INTRODUCTION

Air pollution problems can be directly related to the performance of urban systems - energy systems, transportation systems, and land use systems. More specifically, pollution problems can be related to inefficiency in energy use, to the location and density of urban activities, and to the management of land resources.

This report will document the relationship of air pollution to the performance of city systems. It will outline a methodology for evaluating the air pollution impacts of growth and development, and it will provide a framework for incorporating air quality as a criterion in the comprehensive planning process. The intent of any comprehensive planning program is to balance the operational and service requirements of urban systems with the overall community goals of fiscal efficiency, social acceptability, and environmental protection. That is, it is intended to describe how the urban area can best grow and develop given the restraints imposed upon it by technology, cost, social needs, and the limits of natural systems to support and sustain human activities. Air pollution is one of the most pernicious and dangerous consequences of uncontrolled urban development. It is particularly appropriate, therefore, that it be an explicit criterion in the comprehensive planning process and that every attempt be made to describe and pursue development alternatives that will work to mitigate the pollution impacts of development.

This report will describe the framework for analyzing the pollution impacts of urban activities, and for evaluating the system impacts of air pollution control. The common thread in such a process, as with comprehensive planning generally, is the development of land use and population projections - that is, some description of the expected density and extent of urban activities and some notion of the rate at which change is expected. This basic information is used to describe the requirements for transportation facilities, sewerage systems, water systems, and the other facilities needed to support development. Each of these facilities has costs associated with it, and these costs can be calculated in order to assess the feasibility of supporting the expected development. Air pollution must also be considered as one of the costs of development and can be evaluated using planning and modeling tools.

The following chapters will document the process briefly outlined here. The remainder of the introduction will describe in more detail the health and welfare impacts of air pollution - those facts that provide the basic rationale for controlling pollution. The introduction will also outline the legal and regulatory history of air pollution control. This information is of basic importance, since it outlines to a substantial degree the responsibility of public agencies in planning for air pollution control.

Chapter II will describe the integration of air quality criteria in the comprehensive planning process. Since air pollution is intimately tied to the performance of a number of city systems, planning for air quality is essentially a matter of constructing a data system that will reflect the impact of urban systems and a decision making framework that will allow the necessary alterations in plans for meeting air quality standards. Particular emphasis will be placed on the coordination of air quality criteria with two of the systems that from a public policy point of view are critical in the shaping and the management of urban development; these are transportation and waste water systems.

Chapter III will consider the assessment of air quality impacts related to other comprehensive planning elements. This Chapter focuses in greater detail on the analysis and evaluation techniques available through the comprehensive planning process that serve as inputs for air quality analyses; it also includes a description of those additional tools that will be necessary to properly evaluate the air quality impacts associated with regional development.

Chapter IV will consider the assessment of particular air quality strategies as they relate to planning and public investment decisions. That is, one may characteristically find that there is not sufficient flexibility in the design of future land use and population systems to allow the attainment of air quality standards. In this case, more specific air quality control measures must be applied to address the problem. In almost all cases, these measures will have a discernable impact on the functioning of the region and will imply certain social and economic costs in the implementation of these measures. Chapter IV will outline a framework for evaluating these impacts and will suggest criteria for measuring their effects.

Chapter V and VI will deal in greater detail with the issues associated with two of the most difficult analysis areas: social and economic costs. These Chapters will also outline in greater detail methodologies for assessing these costs as they relate to air quality control strategies.

Chapter VII will discuss the implementation phase of the comprehensive planning program. Because air quality is more than a local jurisdictional issue and relates to a large number of planning and operating agencies, the management or implementation requirements of air quality control will be much more rigorous than for most functional areas. Chapter VII will review some of these requirements and offer some general suggestions as to how these requirements can best be met.

Chapter VIII offers the summary and conclusions of the report and will hopefully outline those facts and findings that are most important for other agencies in developing a comprehensive planning program consistent with air quality criteria.

Health Effects

The first task in a comprehensive view of air quality is to review the rationale that lend to the development of air quality standards and the development of a systematic program to control air pollution.

A compelling argument for such a program does exist. In the most basic terms, the control of air pollution is linked directly to the protection of public health, property, and plant life. Air pollutants are known to be very pernicious chemicals, and animal studies have shown them to include both carcinogenic (cancer producing) and mutagenic (producing genetic damage or birth defects) compounds. Even in minute amounts, these chemicals can have long term effects on human health. Other pollutants have been linked to respiratory and arteo-vascular diseases. Carbon monoxide, by replacing oxygen in the blood's hemoglobin, places an additional burden on the circulatory system and causes heart strain and the aggravation of existing heart problems. Air pollution may also contribute to respiratory diseases such as emphysema and chronic bronchitis. Another aspect of the health problem is the extent to which exposure to pollution increases the body's susceptibility to other diseases, normally considered unrelated to air pollution. For example, the average human inhales millions of bacteria everyday. Most of them are harmless or can be warded off by the body's defensive mechanisms. But persons already debilitated by air pollution may have a harder time fighting infection, viruses, and even the common cold. A further description of air pollutants and their effects is provided in Appendix A.

The Other Costs

A number of research groups have attempted to put a price on the damage done by air pollution. While most of the costs can not be measured in dollars or are hidden by a number of other factors, these cost analyses do provide some perspective of the burden imposed by air pollution. The President's Council on Environmental Quality, for example, recently reported that the outlays by government and private industry for pollution control would total approximately $16 billion for 1975. They also estimated, however, that the damage to people, property, and vegetation would total from 2.5 to 4 times this amount.

These data also serve to counterbalance the argument that pollution is the price of "progress", or an inevitable concomitant of economic growth. Walter Heller, former Chairman of the Council of Economic Advisors, argues that the annual increase in our

National output is overestimated unless the losses from pollution of the environment are recognized as a debit item on the Nation's account books.[1]

Other losses, though difficult to quantify, are no less tangible. Ponderosa pine stands in the Angeles and San Bernardino National Forests are quickly dying as a result of smog carried 60 miles from Los Angeles. Recent research in the Adirondack Mountains suggests that fish losses in otherwise pristine lakes can be accounted for by increases in water acidity produced by "acid rains" floating downwind from industrial centers such as Buffalo, Rochester, and Syracuse, New York.

In summary, people generally under-evaluate the danger of "tasteless, odorless, and colorless" gases that have accompanied growth in this Nation. And certainly few episodes are as dramatic as the eight day inversion in 1948 in Donora, Pennsylvania that caused a 400 percent increase in mortality rates or the four day London "fog" of 1952 that caused 4,000 excess deaths. However, it is eminently clear that air pollution is more than an inconvenience and far more dangerous than a simple combination of smoke and fog. It is a serious problem that should and can be controlled.

Regulatory Framework

The legislative history of Federal involvement in air pollution covers a period of over 20 years. From 1955 to 1970, the agency responsible for carrying out the laws passed by Congress was the Department of Health, Education, and Welfare (HEW). During this period, air pollution was essentially controlled through the development of standards which could be met by existing technology. 1970 marked a fundamental change in Congressional policy towards pollution control. Congress adopted through the 1970 amendments to the Clean Air Act a policy which forced technology to catch up with air quality standards. EPA also became the implementing administration in 1970 with broad authority to set maximum pollution levels and to develop enforcement procedures. Congress, in fact, charged EPA with the mission of attaining clean air to the degree necessary to protect the public health and welfare.

Authority for implementing and enforcing the provisions of the Clean Air Act was left with the States and local governments. However, if they do not accept or fulfill this authority, Federal intervention is mandatory.

1970 Clean Air Act

There are essentially three programs developed in the 1970 Clean Air Act to achieve clean air standards. Section 110 calls for States to formulate Implementation Plans for each air quality control region with the States. These implementation plans describe in detail how National Ambient Air Quality Standards are to be achieved and maintained. The second major provision for achieving National standards is found in Section 111, requiring the EPA to develop New Source Standards for stationary pollution sources. These performance standards set limits on the amount of pollution that certain kinds of stationary sources can emit, and they are to be set at levels requiring the use of the best system of emission controls, taking into account the cost of the system. Each State is required to submit to the EPA Administrator a procedure for implementing and enforcing standards for new source performance. The third major program of the Act is embodied in Section 202 which requires the EPA Administrator to prescribe Emission Standards for Moving Sources. Section 202 calls for a 90 percent reduction (over the 1970/71 level) in the emissions of hydrocarbons, nitrogen oxides, and carbon monoxide originating from light duty cars and trucks. This reduction has been translated into a set of emission standards for new motor vehicles.

These provisions of the 1970 amendments to the Clean Air Act still constitute the fundamental basis for current clean air programs. The Act, however, has been implemented through a set of administrative regulations and these have been modified, in turn, through a number of court cases. One of the most important of these legal actions and the one that sets the framework for advanced or comprehensive planning in the control of air pollution is the case of National Resources Defense Council vs. Environmental Protection Agency heard before the U. S. Circuit Court of Appeals for the District of Columbia.

In this case, the EPA Administrator's approval of implementation plans for the achievement of air quality standards was challenged on several grounds, including the contention that the plans approved were not adequate to ensure maintenance of the National ambient air quality standards once such standards were attained. The court ruled in favor of the National Resources Defense Council and required the Administrator to review all State implementation plans. The Administrator was required to disapprove all plans that did not contain measures to ensure maintenance of the primary standards after the statutory attainment date, or that did not analyze maintenance in a manner consistent with EPA regulations.

Consequently, the EPA Administrator determined that no State plan contained all the measures necessary to ensure maintenance of the standards. In addition, no plan had adequately analyzed the impact of future growth on air quality for any significant period of time. On March 9, 1973, the Administrator disapproved all State plans with respect to maintenance of standards. As a result of the public hearings and the development of these regulations, the Administrator determined that a comprehensive growth analysis should be specifically required of the States in order to make maintenance provisions and implementation plans fully acceptable.

Though the assignment of these planning tasks has been placed with States, regional level organization is perhaps the most consistent and logical choice for such an effort. In Colorado, the voluntary participation of local governments in Councils of Governments allows for the coordination of comprehensive planning among local jurisdictions and provides for the direct participation of elected officials in the design of policies and programs. In addition, it is the organizational unit designated for management of the transportation planning program by the Department of Transportation and for the water quality planning program by the EPA; consistency among programs, it would seem, could best be realized by using the same geographic and organizational framework for air quality planning.

Recent guidelines published by EPA for the preparation of air quality maintenance plans [2] allow the Governor to designate the agency responsible for plan preparation. In so doing, the EPA recognizes the relevance of regional organizations to such planning problems and anticipated the provisions of the 1977 Clean Air Act amendments which encourage greater responsibility for regional organizations in air quality planning.

Clean Air Act Amendments of 1977

On August 7, 1977, the President signed the Clean Air Act Amendments of 1977 (Public Law 95-95). These amendments represent the most extensive modification to the Act since its initial passage and set forth both new policies and new implementation strategies for attaining air quality standards.

The planning requirements for regions that exceed any national air pollutant standard (non-attainment areas) are dealt with in Part D of the Amendments. Major planning, implementation, and enforcement responsibilities are to be jointly determined by the State and elected officials of affected local governments. Where feasible, responsibility for the control strategies shall be assigned (by the Governor after consultation with local elected officials) to the metropolitan planning organization for transportation. In cases where the national primary air quality standards for photochemical oxidants or carbon monoxide have not been met, a revised transportation control plan must be formulated and implemented to attain primary standards by December 31, 1982.

Exceptions may be granted to this date if the State demonstrates to the EPA Administrator that standards will not be met despite the implementation of all reasonably available control measures. In such cases, the period for compliance can be extended to December 31, 1987 where other measures necessary to provide for attainment have been identified.

Major plan provisions of the revised State Implementation Plan include:

- incorporation of all reasonably available control measures to be implemented as expeditiously as possible
- identification and commitment of the financial and manpower resources necessary to carry out the plan provisions
- inclusion of written evidence that legally enforceable documents have been adopted specifying the requirements, schedules, and time tables necessary for compliance
- progress toward reduction in emissions from existing sources through application of reasonably available control technology
- documentation of public, local government, and state legislative involvement and consultation in the planning process
- permits for construction and operation of new and modified stationary sources and the appropriate emission limitations.

In addition to these latter requirements for the operation of stationary sources, Section 173 also makes law the emission offset policy. This policy requires that new facilities may only locate in non-attainment areas if the allowable emissions from the new source are more than offset by reductions in emissions from existing sources and other new sources. (See "emission offset policy" in Appendix A for additional detail.)

Additional transportation planning guidelines are to be provided through directives listed in Section 108 of the Amendments. These guidelines will define in more precise terms the relationship of transportation planning to air quality planning. In summary, the guidelines call for transportation planning to consider not only efficiency, safety, cost-effectiveness and other system measures, but must include a program of transportation projects and system management measures that will provide for reduction in transportation system pollution emissions. This planning work must be comprehensive in scope and include the investigation of all appropriate alternatives for attaining air quality standards and must describe the health, welfare, economic, energy, and social effects of the plan provisions.

Section 176 of the Amendments adds further weight to these provisions by specifying that the metropolitan planning organization shall not approve any plan, project, or program, other than for safety, mass transit, or specific air quality improvement projects, which does not conform to the provisions of the State Implementation Plan.

Subsection (d) of Section 176 further specifies that federal agencies shall give priority, consistent with statutory requirements, for the allocation of funds to implement portions of the revised State Implementation Plan. This subparagraph particularly addresses the programs of the Urban Mass Transit Administration and the Department of Housing and Urban Development.

Section 316 of the Act explicitly addresses the relationship of air quality planning to the construction of sewage treatment facilities where such treatment works are not consistent with achieving air quality standards. The EPA Administrator is authorized to withhold, condition, or restrict the making of grants for sewage treatment facilities if such facilities would result directly or indirectly in increased emissions not provided for in the State Implementation Plan (SIP).

Other provisions of the Act may also be of interest to comprehensive planning organizations, though they do not fit in a particular planning category. Section 118, for example, is particularly important for those regions where federal facilities are significant employment and pollution generators. The Act states unequivocally that federal facilities shall comply with federal, state, and local requirements for the control of air pollution to the same extent as any nongovernmental entity. Other funding, planning, and implementation provisions are better understood by investigating the particular language of the Act, particularly Part D. This summary does provide, however, a general overview of the additional responsibilities, sanctions, and coordination tasks required by local governments and metropolitan planning organizations.

Transportation Planning Guidelines

The 1970 Federal Aid Highway Act added Section 109 (j) to Title 23 of the United States Code which directed the Department of Transportation to develop and promulgate guidelines to assure that highways constructed with Federal funds are consistent with plans for the implementation of air quality standards. In 1974, the Federal Highway Administration published final regulations setting forth the procedures for establishing such consistency. The regulations require annual determinations by the policy board of the Metropolitan Planning Organization that the transportation plans and programs of the agencies are consistent with air quality criteria. These procedures thus act to establish a critical link between air quality maintenance and transportation planning and require a yearly evaluation to ensure that comprehensive planning is in fact taking place.

Section 208 of Federal Water Pollution Control Act

Section 208 of the Federal Water Pollution Control Act Amendments of 1972 establishes a process for areawide waste treatment management planning. This process gives the EPA, the individual States, and local governments a planning tool which allows them to plan how they can best meet National water quality goals. In October, 1975, Program Guidance Memorandum AM-14 was sent to Water Program Directors; this document sets forth procedures that are to be required as part of the 208 planning grant program for the coordination of air quality maintenance planning and waste treatment management planning. As part of the reporting procedure, the planning agency responsible for each subject area must ensure that consistent data and projections are being used, that control strategies do not conflict, and that the programming of infrastructure (roads, interceptors, treatment facilities) will not result in violations of standards for either air or water quality.

As a further "encouragement" to ensure consistency between water quality plans and air quality plans, EPA Revised Program Guidance Memorandum: SAM-8 (November 15, 1976) specifies that EPA will not approve water and air quality plans which are in conflict. Specifically, plans will not be approved which have conflicting projections, conflicting control strategies, or allow for construction of infrastructure (roads, interceptors, treatment facilities) which would result in standards violations in either medium. An approved water quality management plan in turn, is a pre-requisite for EPA participation in the funding of wastewater treatment facilities.

In addition to the review requirements, Guidance Memorandum SAM-8 outlines a methodology for coordinating the 208 program with air quality planning activities. The EPA also provides that 208 program funds may be appropriated for assessing the air quality impact of the development scheduled through the water quality planning process. Examples of coordination activities eligible for 208 funds include development of:

- Common data bases
- Common public participation programs
- Common plan adoption and revision procedures
- Common institutional mechanisms for plan adoption, implementation, and revision
- Control strategies or measures that will achieve the objectives of both air and water quality programs
- Statutes, regulations, or administrative procedures relating air, water, and land use
- Common impact assessment methods, procedures, and criteria
- Air quality assessments of existing or projected development to be served by wastewater treatment facilities
- Strategies for mitigating any adverse air quality effects from water quality management plans

Detailed questions regarding the tests to be performed and the apportioning of costs should be addressed to the EPA Regional Administrators at the time the work program or work program amendments are made. Because of the variability of air and water quality problems and the differences in data and funding availability, no single formula exists for defining the scope of the air quality analyses to be included as part of the 208 planning process.

HUD 701 Planning Program

Local agencies that draw up community development plans to comply with the Department of Housing and Urban Development's comprehensive planning assistance program must allow local air quality agencies to review the plans for consistency with the State Implementation Plan (SIP), according to an agreement signed by EPA and HUD. The interagency agreement also specifies that local community development agencies are to review air quality implementation plans for consistency with the land use provisions of the area's comprehensive plan. Section 701 of the Housing Act of 1954 specifies that applicants for comprehensive planning assistance from HUD must include land use and housing elements in their plans.

Before recipients may qualify for continued comprehensive planning assistance, they must include those land use measures identified as necessary for attaining and maintaining air quality standards. The agreement also specifies that comprehensive plans must reflect any land use provisions necessary for the prevention of significant deterioration of air quality. This interagency agreement is now reflected in HUD's regulations for review and approval of 701 plans (24 CFR 600).

COMPREHENSIVE PLANNING AND AIR QUALITY

Planning for the attainment and maintenance of air quality standards is not an isolated planning problem. Air quality is intimately tied to the performance of other urban systems, particularly land use and transportation. Air pollution can be directly related to the use of fuels or energy in urban areas. Because of the closely associated links within energy systems, transportations systems, and land use activities, coordination of air quality considerations in the planning process is a necessity if there is a realistic hope to maintain strict ambient standards for air quality. Since the planning process is prescriptive rather than remedial in its application, it also offers the best hope of designing urban systems with a minimum of cost and disruption. Infrastructure such as highway systems and sewer systems would be prohibitively expensive to replace or relocate. Once such systems are in place, the only alternatives for air quality control will consist of more disruptive changes in the way cars are used, in the way people travel to work, in the costs we pay for urban services, and in the amounts and kinds of fuel we are allowed to use. Many urban areas are already faced with these alternatives. A comprehensively designed planning program, however, offers the potential to minimize the disruption involved in meeting environmental standards by careful attention to the location, density, and timing of urban development and through the provisions of urban services that carefully match the environmental constraints that accompany urban development. In its proper context, air quality planning can be viewed not as another attempt to impose a set of constraints on local decision making, but rather an opportunity to achieve, consistent with other planning goals, a quality of life standard that will ensure the long term economic and physical viability of our cities.

In a region that approaches or exceeds National air quality standards, there will inevitably be a weighing of land use alternatives and tradeoffs will be made among development objectives. There will almost certainly be conflicts and many of these will not be resolved in a optimum or universally acceptable fashion. Downtown urban renewal, for example, represents one of the most commonly applied tools for central city revitalization and may offer the only hope of creating a solid tax base and community focus for a city. The central business district (CBD), however, is characteristically the area within a region with the greatest density of autos and people and is the area most likely to regularly exceed pollution standards.

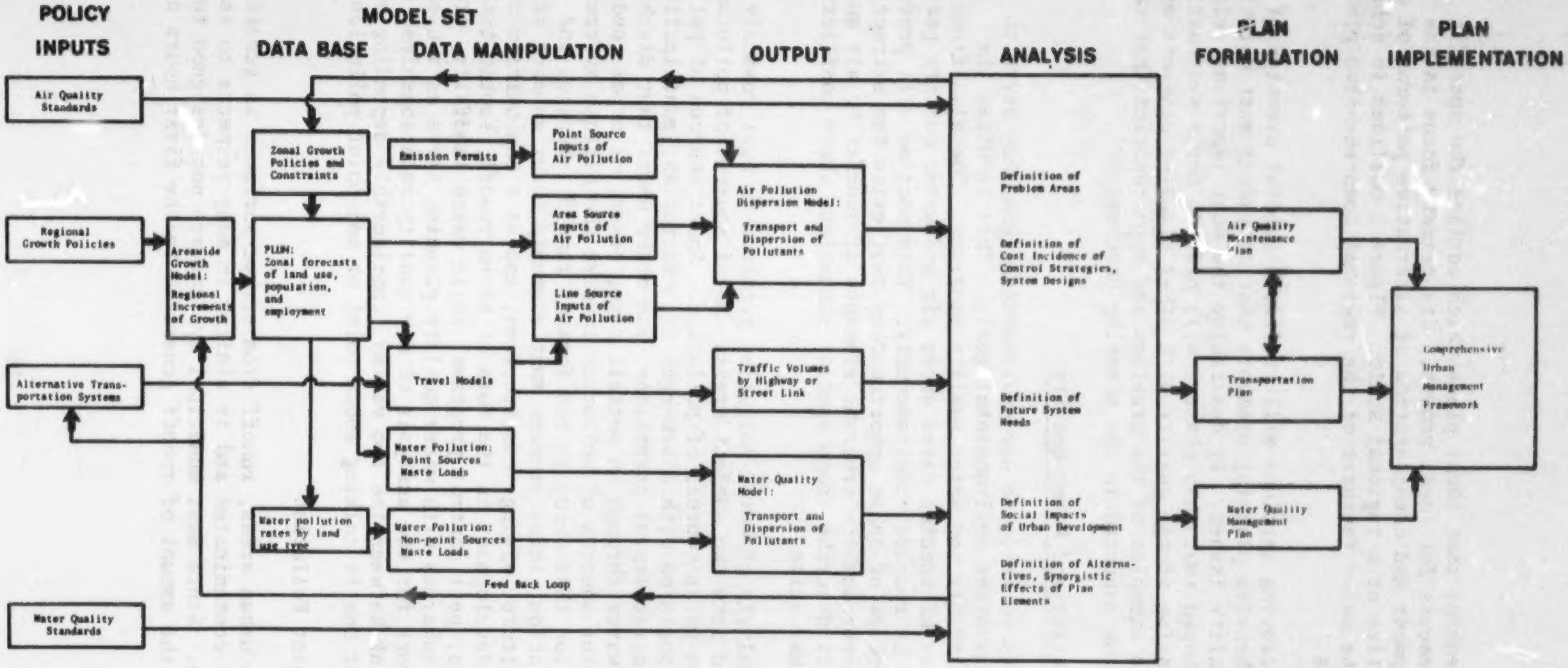
Outlying areas create their own set of problems. Because they have been more recently developed, they are generally auto oriented with low density development and a massive transportation grid to accommodate this development. These areas are also the ones experiencing greatest pressures for growth and place the greatest demand on government for new schools, new sewer and drainage systems, and new roads. Because of their overwhelming auto orientation, the strip commercial zoning, the long distance commuting, and other features, these areas are also particularly suited for the creation of corridors that will regularly exceed pollution limits. Facilities that are most demanded within the urban area, therefore, may form the land use pattern that is particuarly conducive to air pollution problems once these areas are fully developed.

The first step in outlining a comprehensive planning process to address these problems is to define what we mean by the process. While every reader knows what comprehensive planning is, there may not be universal agreement among individuals. This is particularly the case when current practices in planning are constantly changing. One finds for example, that the concept of a comprehensive plan as a multi-colored map with clearly defined uses assigned to specific geographic areas is being supplanted more recently with the concept of development policy sets or impact criteria which define the appropriate criteria for development rather than attempt to define the place for each kind of development.

For the purpose of this report, then, comprehensive planning includes the following features: it is regional in scope and deals with regional labor and employment markets, regional transportation systems, regional population growth, and with environmental problems that like air quality are regional in scope. The basic process is the projection of alternative land use, employment, and population information for zones within the metropolitan areas; these forecasts define to a substantial degree the land use future expected for the region and provide the basis for calculating the infrastructure and urban system requirements for accommodating regional development. Once resources are matched with growth forecasts through a set of functional plans, a management framework is designed which outlines the policies that will lead to the appropriate future.

This plan is therefore at a different scale from functional plans which investigate in detail the development of a particular sector or service, e.g., open space systems, waste water treatment systems; functional plans are important, therefore, in specifying how regional resources are to be used. The comprehensive plan is

FIGURE 1
COMPREHENSIVE REGIONAL PLANNING PROCESS


POLICY INPUTS
MODEL SET
DATA BASE
DATA MANIPULATION
OUTPUT
ANALYSIS
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more general that local plans which outline the specific requirements for local growth. Its primary focus is the development and consideration of alternative patterns of urban activities at a regional scale. Figure 1 outlines in schematic form the major features of the regional comprehensive planning process.

The following sections will provide a general overview of the comprehensive planning elements that interface most directly with air quality issues. By describing the most important relationships, it is hoped that this chapter will provide for a systematic integration of air quality with other planning elements and provide examples of the problems and opportunities that can most likely be expected in the planning process.

Air Quality and Water Quality

Attempts to maximize one environmental goal may serve to maximize other environmental goals. This is often the case with air and water quality programs. One also finds a number of special cases where air and water quality goals cannot be reached simultaneously. This section will provide an overview of those opportunities that exist for extracting from water quality programs elements of benefit to air quality and will describe those special situations where conflicting goals may arise.

The analysis of water pollution problems is most commonly divided into two subject areas: point sources of pollution and non-point sources of pollution. Point sources of pollution are associated with discharges from factories, municipalities, large agricultural operations, and other users that discharge waste water through an outfall pipe, sewer, or other conduit. Non-point sources of pollution involve the diffuse sources of pollution that occur in the form of runoff, seepage, and percolation; these sources most commonly occur as part of agriculture, mining, construction, and as a concomitant of urban development in the form of storm runoff, septic tank seepage, pest control programs, solid waste landfills, etc. These subareas with water quality planning serve as a useful framework for the analysis of air quality relationships, since the link between the two varies considerably depending on whether one is talking about point or non-point pollution.

Non-Point Pollution

Within urban areas, runoff from street surfaces is generally highly contaminated and is similar in many respects to sanitary sewage. Since most municipal systems are not designed to treat the amount of runoff generated in the first hours of a moderate to heavy storm, control measures designed to reduce and divert runoff is extremely important for water quality control. Efforts to control runoff may vary considerably, however, depending on differences in land use, climate, topography, soil type, vegetation cover, distribution of precipitation, variability of precipitation occurrences, nutrient addition to soil, animal and human population densities, etc.

Particularly in the semi-arid west control of erosion, construction activities, and the use of undeveloped land is extremely important in order to minimize the amounts of soil that enter the air or water supplies as pollutants. Though no attempt has been made to specify the correlation, a great number of the programs intended to stabilize soils for water pollution control would have approximately the same magnitude of effectiveness in controlling air pollution by reducing fugitive dust. Source abatement strategies that focus on vegetative cover on open lands, grassed waterways for conveyance of runoff, and detention plans to control the greater erosion potential of urbanized lands are examples of water pollution strategies that have particular relevance to air quality control.

In addition to source abatement, there are a number of technical abatement alternatives that have applicability to air pollution control. Municipal street cleaning, for example, is one program of contaminant removal that may constitute an important element of both air and water quality control. Again, this kind of program has special relevance in the west where wind-blown dust may cover streets in the windy months and where street sanding is used extensively during storm periods in winter months. This pollution, if it does not enter the water regime as an additional sediment load, will almost certainly enter the air as cars pulverize and disperse the sands.

Control strategies do not always mesh, however, and there may be serious reservations to particular pollution control programs for non-point sources. Detention ponds, sediment basins, and other kinds of diversion structures are a viable and relatively inexpensive means of controlling non-point sources. However, as sediments accumulate, such structures could easily become dust bowls and in the arid western states would be a constant source of fugitive dust.

In summary, one can expect water quality planning programs to generate a large amount of information relative to non-point sources of pollution that would be valuable for air quality planning. Such material must be reviewed with a critical eye, however, to minimize the use of those strategies which may exacerbate air pollution problems.

Point Sources of Pollution

The relation of point source control to air quality is provided through the land use element of the planning program. Of most importance is the relation of future development patterns to the cost and technical criteria for controlling water and air quality. In general, one finds that the cost of municipal treatment systems can be minimized by encouraging a continuous development pattern, increasing building densities, allowing for cluster development, and by similar strategies which tend to reduce the size and extent of the sewerage collection network. There also exist economies of scale in the construction of waste treatment plans that would encourage the development of existing metropolitan areas over more isolated satellite development. These general guidelines do not conflict with air quality strategies as long as considerations dealing with very high density areas or pollution "hot spots" are taken into account.

Other land use related information generated through water quality management programs can be applied to an analysis of air quality problems. The legal framework for land use decisions directed to water pollution problems applies to a substantial degree to air quality problems.[3] Organizational and institutional arrangements selected for water quality management might also apply to air quality maintenance. When one takes into account the fact that air basins often correspond roughly to water basins, there is a certain logic to creating a parallel or integrated structure. This coordination is particularly important in the planning stages of air and water quality programs and has been reflected in the encouragement on the part of EPA to assign responsibility for 208 planning and air quality planning to the same regional organization where such an arrangement is possible. A closer look at management strategies for air quality may also demonstrate that there is sufficient logic to create a regional control organization that would be responsible for both air and water quality maintenance.

Industrial Water Users

Industries may be significant generators of point-source pollution. One can also visualize cases where management programs that would be most cost-effective for industrial waste water control may place a severe burden on air quality. This would seem to be particularly the case where pre-treatment of industrial wastes are required. If there are economies of scale to be realized by locating several industries with easy access to a pre-treatment plant, there would be a greater likelihood that these industries would cause air quality standards to be violated. Depending on the type of industries, therefore, special consideration must be given to those cases where pre-treatment plants are to be built. These considerations would include the types of industrial processes involved, their contribution to air pollution, the location of the industrial site in relation to existing air quality problems in the basin, and the adaptability of proposed industries to greater pollution controls.

Power Plants

Electrical power plants represent a special case where air and water quality relationships can be complex. Thermo-electric plants use large amounts of water for cooling; they will increasingly depend on coal as a fuel; and in addition to problems of air and water pollution, they contribute fly ash and other products which pose solid waste disposal problems. They indirectly contribute to another set of environmental problems related to the extraction of coal, the mining of limestone for sulfur dioxide controls, and the shift to other resources as a means of reducing the consumers' utility costs. These relationships as they apply to the expansion of electrical generating facilities within a region are very difficult to assess and would constitute a major research effort for any agency that wished to evaluate systematically the environmental impact of power facilities. However, a number of these issues can at least be outlined in order to provide some structure for managing air quality and related problems.

Since power plants use large amounts of water, they are characteristically located along major drainage channels. The location of power plants along the bottom of the water basin may also be advantageous since these channels often are the major axis for rail and highway systems in the Region. New plants, of course, will be increasingly dependent on rail lines for the delivery of coal.

From an air quality point of view, the location of major sources of air pollution at the bottom of the water basin is an unfortunate decision. During inversion periods, topography and meteorology combine to create a canyon or box effect that traps pollutants and results in violations of standards within a very short period of time - typically during a rush hour period. The problem of topography and drainage may be compounded where prevalent winds parallel the direction of the drainage. Pollutants tend to wash back and forth along the valley, further complicating the problem. When regional wind patterns are synchronized with micro-climate features related to the daily canyon cycle of falling, night time cool air and rising, day time warm air, violations of air quality standards are also likely to be the case.

Other environmental conflicts can also be cited. Coal piled for storage is often sprayed with chemicals in order to mitigate dust problems. Depending on the chemicals used, such applications may wash off and cause water pollution problems. Fly ash taken from the plant may be stabilized in land fill sites using water. This increases the probability of leaching and may contribute to ground water pollution. Water from a plant's cooling towers may be released to adjacent streams, resulting in both thermal and chemical pollution of the water.

Obviously these observations offer little guidance in terms of managing water and air resources jointly within a region. They do, however, point out the importance of site selection in planning utility expansions; the relation of air quality control equipment to other environmental resources; and the importance of topographical, meterological, and other resource information in making decisions regarding energy development. These considerations would hopefully form the basic elements of a framework designed to evaluate regional alternatives for resource and power development.

Air Quality and Energy

Except for fugitive dust, air pollution is almost always a consequence or by-product of the use of energy. In fact, the most immediate hazard to human health from the use of energy is air pollution. The way energy is used and the rate at which it is consumed, therefore, form a critical part of our consideration of ways to conserve air resources.

Energy use, of course, is becoming an increasingly important issue for a number of other reasons. Our consumption of all forms of energy is rapidly increasing at a time when our control of such resources is increasingly relegated to foreign countries and international corporations. As a result, we are increasingly vulnerable to inflation, oil cutoffs, and strained relations with other nations.

From a policy point of view, the direction to date has been to increase the supply of energy resources from within the country. "Project Independence" has been the most noteworthy formulation of policy in this regard in recent years. There remain, however, a number of unresolved issues with respect to this policy that suggest it may be unwise to pursue such a single minded policy too enthusiatically. Problems of environmental protection, technological feasibility, capital availability, safety, theft or diversion of dangerous materials, and the adequacy of institutions are ones that pose major problems in generating a rapid transition to developing greater domestic supplies of energy.[4]

These problems suggest that not only will the country need to pursue a balanced energy development program that would, for example, encourage research in solar energy at perhaps roughly the scale now dedicated to nuclear energy, but would also focus on positive forms of energy conservation. From an air quality point of view, this would be an optimum strategy, since the use of energy is almost directly related to the generation of air pollution.

At the regional level, there exist a number of opportunities to develop a strategy designed to conserve both energy and air resources. While such strategies cannot ignore the global aspects of the problem as outlined above, they do offer local governments the opportunity to take a greater initiative in controlling the use of energy resources and the air pollution consequences that accrue within the Region. Furthermore, these opportunities occur in policy areas where local governments have traditionally played a strong role: public utilities, land use, transportation, and zoning.

An analysis of metropolitan Wasington was undertaken for the Washington Council of Governments which addressed specifically the relation of energy consumption to land use and development alternatives. [5] Five development scenarios were identified in the study: "Dense Center," "Transit Oriented," "Wedges and Corridors," "Beltway Oriented," and "Sprawl." Among the alternatives it was found that there existed a potential for a nine percent energy reduction if the "Dense Center" alternative was selected over the "Sprawl" option.

The "Dense Center" alternative was closely followed by the "Transit Oriented" plan in terms of the energy saving potential demonstrated. This alternative is perhaps most appropriate from an air quality point of view, since it avoids the higher concentrations of pollutants associated with a dense core area. It was characterized in the study as a plan which provided for the location of major residential and employment areas at the planned stops of the rapid rail system now being built in Washington. Housing densities would be moderately higher allowing for an additional energy savings in the construction and heating of multiple dwelling units. Energy savings in the transportation sector can be attributed to shorter trip lengths, fewer trips, and a higher level of ridership on public transit.

A similar but more modest effort was funded for the Colorado Springs area by the Pikes Peak Area Council of Governments in the analysis of "Options for the Future." Differences in the gasoline consumed in the "Feasible Option" versus the "Infilling and Satellite Cities" alternative indicated that there was a fuel savings of approximately five percent associated with the

"Infilling and Satellite Cities" option. Since neither of the options was selected with the intent of optimizing air or energy resources, it appears certain that greater savings could be realized with additional attention to these elements.

Transportation Planning and Air Quality

The automobile is one of the principal sources of air pollution in urban areas. In Colorado Springs in 1975, vehicular traffic accounted for approximately 96 percent of the total carbon monoxide burden within the metropolitan area.[6] Transportation management is a key element, therefore, in any strategy to control air pollution.

It also appears that automobile manufacturers, particularly those in foreign countries, are close to developing engine modifications that will allow automobiles to approach very closely the statutory limits for pollution emissions. This implies that, except for major metropolitan centers, most urban areas will be able to attain ambient standards for air quality over the long term. The focus of a systems analysis such as this one is not on the single effect of a control strategy on air quality, but the multiple benefits that accrue to an urban system as a result of a set of strategies. The rationale for transportation planning in this context will rest not so much on the air quality payoffs to be realized, but the total effort in reducing the public costs for transportation improvements, in reducing the time spent for commuting and urban travel, in reducing the cost and use of energy resources for transportation, and in creating an urban environment that is designed to a human scale.

Transportation technology should be used to give urban areas the form desired, not cause cities to develop in ways that suit transportation systems. Like other technologies, transportation alternatives are sufficiently flexible to adapt to many possible urban forms. Once it is decided what kind of city we want to live in and the values we wish to maximize, a large part of achieving a comprehensive transportation planning program has been achieved.

In general there are two kinds of strategies that will generate the multiple benefits outlined above. One centers on strategies to improve the flow of traffic; the second focuses on efforts to reduce the number of automobiles on the highway or reduce the number of vehicle miles traveled (VMT). The first of these, though often considered independently, must be closely tied to the second if any long range improvements are to be expected. Pollution emissions characteristically improve after traffic improvements are made, but may increase by as much as 20 to 25 percent after five years. The reason for this is that although speeds are increased over the "no improvement" case, the reduction in emissions associated with the higher speeds may be rapidly overwhelmed by the additional number of vehicles attracted to the improved facility. Researchers conclude that traffic flow improvements should be viewed only as a short-term measure for reducing air pollution unless traffic volumes can be reduced or restrained.[7]

The number of alternatives that exist to improve traffic flow and to reduce VMT is quite large and have been well documented in a number of studies. EPA and the Department of Transportation are two of the best and most accessible sources for such information.

Public transit is a principal example of a strategy to reduce VMT, and thus the pollution contribution of autos.. In low density cities, reliance on conventional buses cannot be expected to maintain the level of service and ridership found in higher density metropolitan areas. Investments in mass transit may only be justified by the social need of mobility for persons unable to use privately-owned vehicles. Only if system improvements are closely coordinated with a comprehensive planning effort designed to support such a system can reliance on privately owned vehicles be reduced. Since the conventional buses represent an acceptable and well tested system, additional consideration of the comprehensive planning implications should be instructive.

In general, conventional large buses are most effective either in high density corridors or among high density development nodes. Clearly, such a system cannot efficiently link the low density residential areas and widely scattered commercial and employment centers that have characterized development in many metropolitan areas. Such nodes or corridors should include not only high density residential components, but should include as many of the essential urban land uses as possible. These would include employment opportunities, commercial centers, and service industries.

Land use administrative policies might be designed to encourage these development patterns enhancing the bus system. Special density bonuses could be given for new developments located along and designed as a part of bus corridors. Greater bonuses would be given if a development is located at the intersection of two bus lines; an area within a quarter mile of three bus lines would be provided even greater incentives for high density development. Parking requirements for developments could also be reduced if they were integrated with public transit systems.

In addition to the land use planning elements, design criteria would be critical to encouraging such a system. Public transit must be convenient and easy to use - ideally, more convenient than auto use. Designs of apartment complexes, for instance, could be oriented to accommodating a bus circuit rather than providing auto parking at every doorstep. Commercial and service areas must be similarly oriented so that buses are available within a few steps of business entrances. Links must be designated to facilitate the ingress and egress from the transportation grid to the development nodes; facilities may also need to be altered to provide preferential treatment of bus traffic over auto traffic.

The private sector could also be encouraged to participate in other ways. Parking refunds at stores could be supplemented or replaced by transit refunds. In return for conserving asphalt and land in parking lots at their place of employments, transit riders could be compensated for their contribution to lower site costs through transit refunds. Costs for such subsidies could be offset, in addition, by charging employees who did not participate in car pools or use buses for parking their cars at the place of work. Working house could be made more flexible to allow workers to arrive and leave at times that would fit better with transit schedules. Special awards or recognition could be given employees that were most conscientious in using transit facilities. Contracts with private security guard companies might be extended to cover not only the facility, but the area between the facility and the bus stop during those hours when employees are entering and leaving work.

In short, the commitment of a community to a conventional bus system must involve not only the decision to buy new buses and improve the support facilities, but will depend to a large extent on the contributions of the public and private sectors to make the system feasible and self-supporting. These decisions will involve innovations, testing, and a redistribution of the costs and benefits associated with private auto use. The tremendous potential of comprehensive planning, however, lies in the fact that if fundamental changes are made now, urban form can be shaped with a minimum of disruption and with advantages accruing both to the private and public sectors.

Other transportation alternatives could also be applied to metropolitan areas. Para transit systems include a class of service between the automobile and the conventional bus; primary examples would be vans, mini-buses, and taxi-cabs. In low density sectors of metropolitan areas, these alternatives might, in fact, be operable with greater efficiency than the larger buses now used.

As with bus transit alternatives, the use and potential of para transit systems have been well documented in a number of sources. Success of the various schemes has been mixed; a number of critical variables must be weighed before one can be reasonably assured of operating with success. These include the cost charged to the passenger (ridership is inversely proportional to fare), the length of trip (short trips to work do not generally encourage use of public transit), labor regulations affecting the selection of driver (full time paid drivers raise the cost of para transit significantly), and the comprehensiveness of the system (as the service area and frequency of service declines, ridership drops).

A van pool system has many advantages of mass transit while avoiding the large costs associated with full time drivers, dead-heading buses back to their origin after delivering workers, etc. While it does imply some risk to the employer and some managerial time, it can be a very successful program if enough thought is given to its management. Such things as providing preferred or weather protected parking spaces to van pools, providing incentives to the driver to properly handle the vans, and providing an efficient matching program at the place of employment will be important factors in determining the success of such a program.

Other alternatives, though limited in their application, may be useful in addressing particular emission problems. The development of bikeways and the encouragement of bicycle use falls in this category. With increasingly strict auto emission standards, a greater portion of the emission problem will be associated with the number of trips made by auto users and not the length of trips (VMT). This is true because autos equipped with catalytic convertors are particularly inefficient with respect to the control of emissions when the auto is first started (cold starts) and when the engine is stopped after a trip (hot soaks). Strategies which reduce the number of trips, and thus the inefficient starting up and shutting off of autos, will be important regardless of the length of the trip taken. Bicycles are useful alternatives for reducing the number of auto trips when short distances are involved. Data from a recent nationwide transportation study indicated that 25 percent of auto trips are less than 1.5 miles long, and another 13 percent are between 1.5 and 2.5 miles.[8]

In summary, potential does exist for undertaking alternative transportation programs. Their attractiveness as an alternative to traditional transportation modes is linked to the multiple benefits associated with their use: reduction of traffic congestions, improvement of air quality, conservation of energy, and reduction in parking space requirements. Obviously, such programs must be carefully planned and begun on a relatively small scale; however, their potential for inclusion in a longer range energy and air quality program warrants greater experimentation within the region. Experience in a number of urban areas indicates that such experiments can be self supporting, will make commuting easier and less costly for urban residents, and can achieve the multiple system benefits described above.

From a comprehensive planning point of view, it is important to remember that transportation control actions have a significant impact on urban systems, and will form one of the critical elements in a long term strategy for resource conservation, fiscal savings in road construction and maintenance, and the shaping of urban form. Portland, Oregon's experience in van pooling with 22,000 employees, for example, was able to demonstrate a savings of 76,833,212 vehicle miles traveled, 5,946,843 gallons of gasoline used, $12,216,480 in commuting costs, and 5,605 tons in reduced pollution emissions in a single year.[9]

Air Pollution and Open Space Planning

Open space planning can be an important complement to air quality planning efforts, though perhaps not in as direct a way as other elements of a land use plan. The primary benefits of open space in this context are related to its potential function as a buffer zone, or as a mixing and dispersal area for air pollutants.

In certain urban planning cases, however, it can play a much more important role in constructing a comprehensive planning program. One of these cases would be in the design of malls for urban core areas. The mall concept has several applications, but is generally intended as a means of revitalizing downtown areas, of providing a richer environment for the pedestrian, and for focusing the urban center on a more human and natural scale. A very important correlate of this planning is that it frees the downtown shopper or worker from the noise, danger, and air pollution of the automobile. The considerable amount of space previously relegated to the automobile can be redesigned to enrich and enhance the urban landscape through the design of the mall. The open space design plays a critical role in the redesign process, since the attractiveness, ease of use, and ultimately the competitiveness of the urban core area will rely substantially on the attention given to the design and function of the mall area.

A second special role of urban park design relates to the creation of another automobile alternative, the bikeway. Abandoned railroad beds, drainage ways, and other linear systems can be used as bikeways. Again, it must be emphasized that urban dwellers will not abandon their automobiles unless other alternatives are attractive and convenient. The development of these corridors must necessarily incorporate open space planning as part of the design process. In mild climate areas, the use of such bikeways may not only be a safe, relatively pollution free, and invigorating means of commuting, but provides an enjoyable natural experience with the change to experience waterways, natural areas, and the accompaniment of song birds on the way to work. When compared to the normal asphalt, traffic light, and car bumper landscape that accompanies urban commuting, it is difficult to imagine that more persons would not be drawn to such alternatives.

A third important application of open space to air pollution problems concerns the design of schools in urban areas. Since school age children are more highly susceptible to the effects of air pollution, particularly related to respiratory disorders, the design complement of school site and open space can be of special importance. Generally, designers have developed well the school park concept. School sites are often combined with park areas so that maximum spaces are available for designs that buffer schools from the danger, noise pollution, and air pollution associated with streets. When such designs are integrated with a street system that allows the location of school sites adjacent to neighborhood streets or other low volume traffic paths, air pollution impacts can be ameliorated to a large degree.

Apart from these special cases, the role of open space with respect to air quality maintenance relates primarily to the potential to use such areas as buffer areas or zones in the vicinity of large polluters. Industrial areas, airports, power plant sites, and high-volume highways are examples that would be particularly appropriate for such treatment. The development of such buffer areas is more confined, however, since they do not have the potential for development as recreation areas in most cases. An exception might be the uses of areas around airports as moto-cross parks in order to divert a portion of the motorcycle traffic that presently use public lands for their travels. In general, however, such areas will be difficult to maintain as multiple use areas. Assuming zoning controls can be applied to maintain the areas as agricultural, the management of such areas may be relatively straight forward. If pressures for developing lands to their highest potential, despite environmental consequences, make such a strategy difficult to pursue, more stringent land use controls in the form of air pollution density controls, indirect source review procedures, or other alternatives may need to be applied.

Residential Planning

Residential areas are responsible for the generation of pollutants from two souces: home heating and automobiles. In a community where natural gas is the primary heating fuel, the primary pollutants generated are particulates, hydrocarbons, and oxides of nitrogen. A low density community of 10,000 housing units would produce on the order of 150 pounds of particulates per day, 300 pounds of hydrocarbon per day, and 1,000 pounds of oxides of nitrogen per day.[10] While it is unlikely that residential areas using natural gas could be the principal cause of an air pollution episode, the increasing shortage of natural gas will cause communities to seek other sources of energy for home heating. Part of the short fall may be make up by the use of electric or solar energy. In the case of the former, pollution contributions shift to the analysis of power plants within the region. In the latter case, the air pollution consequences are essentially nil. A third alternative, coal heating, may be used for heating within the home and the pollution consequences may be more significant. Obviously home furnaces cannot include the sophisticated pollution control equipment that is used for coal-fired power plants, nor can one expect the careful monitoring and maintenance of combustion that is an essential part of power plant operation. What one can expect are units that are quite cost effective when compared to solar or electric heating and which would, therefore, have the potential to capture a significant share of the market created by the natural gas shortages. These consequences, then, must be evaluated in some detail in a comprehensive evaluation of future land use patterns. When combined with other neighborhood uses which may come to depend on coal, such as schools, the impact on air quality may be significant.

Cars contribute pollutants to residential areas in the form of carbon monoxide, hydrocarbons, and oxides of nitrogen. On a metropolitan scale, the contribution of auto use within residential areas is a relatively small percentage of the total pollution burden; most of the automobile pollution is contributed by trips from residential areas to some outside destination such as work, shopping areas, or recreational facilities. However, the relation of residential areas to other land uses is of some interest from an air quality planning point of view and has a number of implications for the design and planning of residential areas.

Design Considerations

There are essentially two critical variables in the design of residential areas that affect air quality: residential density and residential location. With respect to building density, the first finding is that higher residential densities contribute less to both automobile and heating pollution burdens. There are a number of reasons for this observation. Multi-family structures are generally more heat efficient since a lesser percentage of the total surface area of the building is exposed to the outside. Even town house construction which shares only one party wall between units can result in a reduction of fuel use and air contamination by one third. It should also be noted that larger multi-family units also offer the opportunity to use a single heating plant which can be designed to higher standards and maintained at a more rigorous schedule for heating efficiency and pollution control. As for auto use, research findings indicate that spatial differences between high and low density communities favor the higher density communities in terms of air quality. It is also found that car ownership varies by housing type and density; this variable is reflected in trip generation equations.[11] While the density variable may reflect an income bias (richer people own their own homes and can afford more autos), a higher density community should reduce the length of trips as well as the number of cars per household.

The second finding with respect to the consequences of building design is that there are multiple benefits to be realized from well designed, higher density residential areas. The Real Estate Research Corporation evaluated six residential alternatives, the critical variables being housing density, the mix of housing types, and efficiency of design. This research project indicated that the high density planned alternative contributed only 53 percent of the total air pollution burden accounted for by the low density sprawl alternative.[12] In addition, the potential for similar benefits in other elements of the urban system was apparent. The report evaluated four factors related to water quality: flooding, groundwater, erosion and sedimentation, and pollutants to surface or sub-surface waters. The community analysis indicated major differences in storm runoff and sedimentation from runoff: the high density planned community contributed approximately 40 percent less pollution from sedimentation and 25 percent less storm runoff[13] than the low density sprawl alternatives.

Estimates of publically supported services such as police protection and fire protection showed similar advantages for more compact and comprehensively planned residential areas. Utility systems - sewerage, storm drainage, water service, gas, and electrical systems - also proved to provide savings in capital and maintenance among the higher density alternatives.[14] Taking into account the environmental impact of development and considering the potential cost savings to both the private and public sectors, then, the design of residential neighborhoods is a critical element in creating an efficient urban environment. Furthermore, the systems analysis points to a consistent set of findings with respect to the most appropriate direction for development. Though there is still a very strong public sentiment towards low density development, the increasing costs of such development will require that a significant portion of new households will need to explore other alternatives. It should also be underlined that there are a range of alternatives; efficient planning does not necessarily require that all new housing be very high density. As indicated earlier in the report, even town house construction provides considerable savings in energy use, pollutant emissions, and construction costs; it is an alternative that also provides many of the amenities associated with single family construction.

Residential Location

The relation of residential areas to other land uses is of special importance since it bears heavily on the use of the automobile. Both the number of trips and trip lengths are associated with the relation of residential areas to the service, employment, and recreational opportunities which support them. One of the most important concepts in realizing a more efficient relation among these sectors is that of mixed land uses. However, land use planning has developed with a singular focus on zoning patterns which separate land uses and which characteristically consider a single structure on a single parcel of land. With this history, an increasing emphasis on mixed use development signifies a major departure not only from public policy and planning, but from the private sector that has evolved towards the design and financing of single use developments. Since residential development seems to be the most problematic and financially precarious element in mixed use development, it is perhaps most appropriate that some additional attention be given to the concept here.

In its basic form, the mixed use development is merely a variation or extension of the nodal development or activity center concept discussed in other sections. The advantages to be realized from such development are associated with the integration of higher density housing, the superior service that can be offered by public transit, the greater emphasis on pedestrian and bicycle modes, the savings to be realized in infrastructure, energy savings, and air quality improvements. There are also a number of consequences that are peculiar to the internal design of such centers. For example, experience has demonstrated that the peak parking demands for different uses occur at different hours. Employment centers attract most traffic during daily working hours; residential areas require most parking for after-work hours. There exists the opportunity in such developments to share parking facilities, therefore, and provide greater cost savings to the developer, a reduction in storm-water runoff from the impermeable surface, and potentially a reduction in particulate pollution from a reduced area of paving that would require sanding during the winter months. Other advantages might be realized in the potential for waste recovery in dealing with large building units The Department of Housing and Urban Development will soon be sponsoring a study to investigate this potential. Finally, the development of such centers provides the opportunity for larger scale development and greater design flexibility by departing from the single use concept.

Development Requirements

Since the mixed-use concept requires a major departure from conventional development patterns and involves a much larger scale of development than is normally the case, the planning demands of such development must be considered in much greater detail. One of the important lessons to be learned from experiences in mixed-use development is that there must be a shared responsibility on the part of the private and public sectors in the development of such centers. Because of the difficult financing and design requirements of a mixed-use center, the private sector must be allowed the flexibility to produce a workable development. The public sector, on the other hand, must have the assurance that the proposed development will achieve public goals and that the development will proceed in a way that is practical from a fiscal point of view. There must be a commitment on the part of both parties, therefore, that such development can be structured for the benefit of both and that the fullest cooperation from both sectors can be relied upon in realizing the plan.

A number of tools are available from the public sector to foster such a coordinated and responsible effort. Planned Unit Development (PUD) codes can be structured to include an activity center or mixed-use variation. Such a code would place greater emphasis on design and performance criteria and less emphasis on precise requirements for parking spaces, building coverage, use relationhips, etc. One "town center" ordinance, for example, has no requirements for parking other than the performance criteria that all parking must be on-site and exclude the use of public streets. The designer is thereby allowed to choose among shared lots, public transit, car pools, parking garages, or any other design solution that would satisfy the parking problem.

Financial tools are also available to the public sector that could be used to facilitate such developments. Industrial revenue bonds, tax increment planning, the designation of improvement districts, and the assemblage of land through Urban Renewal districts are all examples of tools which can be structured to encourage desired forms of development. Each of these, of course, has particular applications and will require thorough evaluation for particular projects. What is suggested here is that a commitment by local governments to pursue such development can be backed with the critical resources needed to make it feasible.

Advanced Technologies

One of the most useful roles of comprehensive planning is to anticipate emerging changes in technology, so that urban systems can be adapted to take advantage of the benefits that can accrue. Because of the interaction among systems, special attention must also be paid to the potentially adverse consequences of these new technologies. A number of interesting examples can be mentioned of technologies that will allow greater efficiencies in the use of energy, water, and waste reuse in the urban sector. We can also expect other major urban systems such as transportation to evolve towards more efficient and less polluting modes as demands of energy, space, and capital resources force new solutions to urban movement problems.

One area of interest that will affect all of us are the changes in residential design that can be anticipated. One can expect designs to be more functional than present in order to conserve water, fuel, and space. On an average basis, 36 percent of the total amount of water used in households is consumed by toilets, for example.[15] Future designs might well incorporate composting toilets as an alternative to conventional system; venting systems will be particularly important in avoiding air pollution, or at least odor pollution problems. Similarly, one might expect innovative designs in the future to eliminate setback requirements for construction to avoid large, water consuming lawns. Design standards will, instead, be written to preserve solar planes and to provide space for gardens, green houses, and play equipment. Spaces between units will be separated by walls rather than large expanses of lawn to preserve privacy, and more efficiently designed patios or atriums will serve as a focus of outdoor activity rather than the lawn.

At a neighborhood scale, one might expect a greater attention to bicycle and pedestrian modes of travel and more efficiently designed links to public transit services. Partly as a result of smaller lot sizes, park and recreational areas will be of greater importance and will be more widely used. The design emphasis will be on the utilization of areas in their natural state in order to avoid maintenance and watering costs.

Each neighborhood or district unit will have as its focus a high density activity center which will provide high density apartment areas, commercial facilities, and business opportunities within a short distance of neighborhood residents. The center will also house its own power plant which will use solid waste from the complex to provide both electricity and heat to surrounding buildings. Asphalt parking lots and streets will be underlaid with heat exchangers to absorb additional amounts of heat to run heat pumps used for air conditioning and heating. Air pollution impacts will be minimized through greater heat and electrical efficiencies and through the decentralization of power generating facilities; greater attention to the development of employment centers as a focus of neighborhood developments will decrease the need for auto commuting and further reduce pollution.

While these ideas may seem too hazy to be relevant, these technologies are now on the horizon. In Sweden, for example, large apartment complexes have been constructed to act as their own recycling center for solid wastes. Cogeneration facilities for heat and electricity were considered for the World Trade Center in New York before special rates were offered by Consolidated Edison.[16] Fluidized bed combustion chambers will allow the burning of solid waste for fuel with minimal pollution effects.

When one considers that zoning and subdivision decisions are being made now that will determine the urban form that will exist twenty-five years from now, the importance of innovative long range planning becomes more apparent. Many of the implications of these technologies will focus on the architectural or design solution to specific problems rather than broader planning considerations. However, certain concepts such as the use of multi-use activity centers as a focus of community development should be pursued now if we are to meet future efficiency requirements for urban growth. Neighborhood design will also be an important consideration if we are to provide the proper balance and protection between community centers and the residential areas they serve. Transportation networks will need to focus on the development of other modes in addition to the use of conventional automobiles for urban travel. And planners and decision makers may find that "Small is Beautiful" is an appropriate maxim for designing urban systems to meet the demands of the Year 2000.

AIR QUALITY ANALYSIS

The analysis phase is certainly one of the critical stages of the comprehensive planning process. It aims to define and locate urban system needs; to evaluate the social, environmental, and economic costs of system development; and to assess the relationship of one system element to another. The creation of the methodology for planning analysis and the selection of the criteria for plan evaluation are critical areas where air quality considerations must be incorporated if the integration of comprehensive planning elements is to take place. Obviously, the scale and scope of analyses within a region will depend to a large degree on the resources available for planning, the organizational relationships among planning areas, the rate of growth within the Region, and those other factors which determine the need for planning.

The most relevant criterion in determining the scale of analysis as it relates to air quality will be whether or not the area now exceeds or expects to exceed ambient air quality standards. Normally, such regions have been designated as Air Quality Maintenance Areas (AQMA), non-attainment areas, or areas requiring Transportation Control Plans (TCP); in general, the State Air Pollution Control Agency will be the best source of information regarding the designation of a particular region with respect to air quality problems.

The analysis framework discussed in this Chapter (outlined in Figure 1) is not intended to serve as a blueprint for all other agencies, nor will it serve to specifically demonstrate how one is to accomplish each of the tasks implied in the analysis. However, it is intended to outline those areas where air quality information can be generated and used and to suggest how this information can be applied as part of a comprehensive planning program. The following sections will deal with each of the major elements of the planning process outlined in Figure 1: Policy Inputs, Modeling, Analysis, Plan Formulation, and Plan Implementation.

Policy Inputs

The formulation of a set of policies for development are fundamental to the planning process, for they define the expectations of the citizenry, they outline the goals and objectives for structuring development, and they provide standards for measuring progress towards some desired future. From an air quality perspective, development standards are represented by the national ambient standards for air quality. These standards, in fact, are the basic criteria which the planner will use to evaluate the air pollution impacts of alternative land use futures. The following sections will deal in greater detail with constructing the data and tools needed to predict future air pollution concentrations.

The Model Set

Land use and air quality models are basic planning tools which can be used to construct and evaluate alternative development options. At the outset, it should be noted that the use of such modeling tools implies a fairly rigorous approach to data collection, calibration, and forecasting. However, these modeling tools are relatively flexible instruments, and metropolitan areas which have or expect to have a population of at least 50,000 should be able to consider the application of such tools. Larger metropolitan areas, of course, have much more complex data problems and benefit to a greater extent from modeling programs.

The current set of land use models are based on a series of "activity allocation" formulations. Examples of such models are the Projective Land Use Model (PLUM), the Urban Systems Model, the Empiric Activity Allocation Model, and the Accessibility Opportunity Model.[17] They are designed to allocate previously determined Regionwide totals of "activity" among a set of sub-regions or zones for each of a series of forecast years. "Activities" are defined within the various models as counts of classes of populations, employment, and land use.

Land use models are designed to reflect the impact which alternative policy decisions in one or more functional planning areas may have on the future distribution of urban growth; that is, they incorporate policy sensitivity. Major emphasis is placed upon the treatment of transportation related policies, particularly those which reflect conventional network characteristics of transportation service. Other aspects of regional development policy, particularly relating to future investment in public utilities, land use controls, development densities, and environmental planning can be handled by several of the models. This coordination is provided by assessing the impact of specific programs in each of several planning areas in turn as requirements of other urban systems. That is, zonal allocations of future employment and population are subjected to a set of constraints, including an upper level of households within each zone, and a set of land consumption constraints reflecting the manner in which vacant land is consumed by development. The result is an internally consistent set of projections of employment, population, dwelling units, and land use by small areas for a given target year.

This information, then, is of basic importance to a number of functional planning areas, particularly water quality, transportation, and air quality planning. (See Figure 1.) In addition, it provides considerable cost efficiency by providing a single set of data which has application to the detailed requirements of a number of functional areas.[18]

For air quality analyses, land use data are principal inputs to the description of area and line sources of air pollution. Area sources of pollution are defined as small residential, institutional, commercial, or industrial air pollution sources that, when summed, represent a substantial source of air pollution. Typically, regional air quality models treat each of the zones in the land use model system as area sources of uniform density; the main inputs to the area source emission calculation routines are the number of acres in the zone, the total residential population, and the total number of people employed within the zone. Though treating the zones as an area source of uniform density is likely to produce some distortion in the results, this methodology is "not so much an inherent problem as a lingering deficiency".[19] Particularly for regional scale analyses, this methodology cannot be considered to introduce any significant errors. Line sources, as we shall see in the succeeding section, are calculated through a set of transportation models.

Transportation System Models

Traffic information is a basic requirement for estimating ambient air quality. One of the end products of transportation planning studies is a summary of projected volumes on major streets in the region under study. A brief description of the transportation planning process will serve to explain the procedure involved in projecting future air quality impacts. Major steps in the forecasting of future traffic include:

- Trip attraction/generation: the trip attraction and generation phase quantifies trips beginning and ending in each zone delineated within a region or study area. Trip generation methods are based on observed relationships between the volume of trips beginning or ending in a particular area and the land use or socio-economic characteristics of that area. One statistical method for deriving trip generation equations is linear regression analysis which assumes that changes in one variable can be precisely predicted when the changes in two or more independent variables are known. These independent variables may include basic employment, non-basic employment population, median family income, number of dwelling units, number of employees by residence, automobile ownership and similar factors. Many of these data, as we have seen in the earlier discussion, are generated through the land use modeling program.

- Trip distribution: the trip distribution process determines the pattern of zone-to-zone travel; that is, the trip volumes generated from the first phase are distributed throughout the study area. Trip distribution equations assume that future travel patterns can be predicted if travel times or costs between all zone pairs are known. The method most frequently employed for estimating zonal trip interchanges is the gravity model, which predicts that the interchange between zones is directly proportional to the number of trip ends in each of the zones and inversely proportional to some function of the spatial separation between zones. Travel time factors are used to express the effect of spatial separation on trip interchange.

- Modal split: this process determines the proportion of trips which use the automobile as opposed to transit. Again, certain data from the land use projections are used to determine the modal split: population density, employment density, and economic status of the tripmaker. Modal split estimates also are based on the relative travel time or costs via the auto and transit modes.

- Traffic assignment: the traffic assignment process assigns trips to specific roads or streets of the highway network or to specific routes of the transit network. For modeling purposes, the network is represented by a matrix of links and nodes, where the nodes describe end points and connections of the links representing highway or transit route segments. Trips are assigned to the links according to travel time and link capacity criteria, in an iterative process. These network models are characteristically available from programs maintained by the State Division of Highways or the Department of Transportation.

The emission of pollutants attributable to a road is related to three major factors. The first of these is the number of vehicles on a segment of road; this information is provided through the traffic assignment process outlined above. The second factor relates to the types of vehicle in operation; vehicles of different size, type, and age emit gaseous pollutants at different rates. In order to simplify the process, characteristics of the national vehicle population are often used where local data on the vehicle mix are not available. The third principal factor relates to the mode of operation of vehicles: starting, accelerating, decelerating, idling, or steady speed cruising. Because driving patterns or the mode of operation are distinctly different on different types of roadway, average emission rates are calculated corresponding to the types of roadway: collector streets, arterial streets, and freeways. These average emission rates or emission factors are compiled in AP 42 Compilation of Air Pollution Emission Factors.[20]

When traffic volume and speed on a road segment are known, total emissions from that segment, usually expressed as emission density, can be calculated. Since air quality analyses are focused on those times when a violation of standards is most likely to occur or worst case conditions, peak hour traffic is of most concern in calculating emission density. This information is usually available from the local traffic or public works department; if peak hour data are not available, the annual average daily traffic (AADT) can be used to estimate peak hour traffic, since peak hour traffic is about eight to fifteen percent of AADT.

The calculation of emissions density for carbon monoxide (or any other auto pollutant) can be expressed as follows:

$$Q_{co} = K \times V \times E_{co}$$

where Q_{co} = CO emission density, $\frac{\text{gm}}{\text{sec-m}}$

V = peak traffic volume, vehicles per hour

E_{co} = emission factor, grams per mile

K = conversion factor

Air Quality Models

The basic tool used to evaluate the air quality impacts of planning actions or development scenarios is an air quality model which simulates the transport and dispersion of air pollutants within an air basin. Models vary in complexity from simple desk-top approximations to computer assisted models which attempt to replicate complex chemical reactions which occur in the atmosphere. Models also differ in terms of the scale of the problem being investigated. One class includes micro scale models which are constructed to analyze particular projects or activities such as shopping center developments or highway links. This report is essentially concerned with the second class of models: regional or mesoscale models. Regional models describe the transport and diffusion of pollutants from all metropolitan sources and estimate pollution concentrations for a large study area. Air quality models generally serve two important purposes: they can substitute for an extensive and costly network of pollution monitors to compute present pollution concentrations, and they can forecast future concentration levels of pollution based on expected regional changes in key urban activities.

Volume 12 of EPA's guideline series for air quality maintenance planning and analysis describes the application of atmospheric simulation models to the investigation of expected air quality problems.[21] The most simple tool which has some purpose in the analysis of pollution problems is called the Rollback Model. The Rollback Model assumes that future concentrations of air pollution are proportional to the ratio of existing emissions to future emissions. That is, it assumes that a given reduction or increase in pollution emissions will result in a similar reduction or increase in pollutant concentrations. It is simply a tool for scaling concentrations up or down to reflect the changes in the total pollution contributions from point, area, and line sources.

In order to apply the model, an air quality monitor must be located at the point where maximum ambient concentrations occur. Since air quality standards are tied to the violation of ambient standards anywhere within the air basin, future estimates of air pollution must attempt to determine any violation of standards. For this reason, the calculation of future concentrations must be tied to the location and measurement of concentrations where maximum ambient concentrations presently occur.

The application of the rollback concept is mainly limited to estimates of expected changes in air pollution at a regional or air basin scale. Since emissions from the entire area are summed, the data will tell the analyst very little about expected emissions within a small area, the future occurrence of "hot spots", the immediate impact of roadway construction projects, or other specific phenomena. However, for planning agencies with limited funds or that wish to estimate the scale of future problems before deciding to undertake a more ambitious program, such a tool can provide a useful short-cut to estimate the scale of future emission problems.

Dispersion Models

A more versatile set of models simulates the transport and dispersion of air pollution from defined sources within the air basin. An atmospheric dispersion model can be described as a mathematical description of the transport, dispersion, and mixing process that occur in the atmosphere. Four variables characterize the atmospheric dispersion process:

1. Wind Speed - determines the "ventilation" rate
2. Wind Direction - determines the path where pollutants are transported
3. Mixing Height - determines the depth of the atmosphere available for vertical spread of pollutants
4. Atmospheric Stability - is a measure of turbulence in the atmosphere. Atmospheric stability is divided into classes A through F in the Pasquill method depending on surface wind speed, solar radiation, and cloud cover. Class A is the most unstable class; Class F is the most stable one.

High wind speeds, unstable atmosphere, and unlimited mixing height accelerate the dispersion process and represent favorable conditions for the dispersal of air pollutants. Low wind speed, stable atmosphere, and limited mixing height inhibit the dispersion of pollutants and are associated with inversion or "worst case" conditions.

Common to the mathematical description of dispersion in many of the models is the use of the Gaussian plume equation or the Gaussian distribution. The ground level concentration of a pollutant from a continuously emitting point source is expressed by the following equation:[22]

$$C\ (X, Y, 0: H) = \frac{2\ \sigma}{\mu} \quad \frac{\exp\left(-\frac{H^2}{2\sigma z^2}\right)}{\sqrt{2\pi}\quad \sigma z} \quad \frac{\exp\left(-\frac{y^2}{2\sigma_y{}^2}\right)}{\sqrt{2\pi}\quad \sigma_y}$$

where

C = Ground level concentration of a pollutant, usually expressed in micro grams per cubic meter (ug/m^3).

X,Y,Z = Coordinates of the receptor at which concentration is estimated.

H = Effective emission height of the point source, in meters.

Q = Source strength (pollutant emission rate), grams per second.

π = A constant, 3.14.

σ_y and σ_z = Lateral and vertical dispersion co-efficients, in meters. These depend on stability, surface roughness, wind speed, and distance between source and receptor. They also depend on concentration averaging time, and their values are available for averaging times of a few minutes.

μ = Mean wind speed, in meters per second.

This dispersion pattern is shown graphically in Figure 3.

Other models such as APRAC [23] allow the addition of other subroutines which calculate the dispersion of pollutants within special areas such as street canyons (streets bounded by tall buildings). Other inputs to the model include traffic distribution, emission factors, and grid coordinates for line, area, and point sources of pollution.

Emissions Inventory Requirements

The detail and coverage of the emissions inventory is a determining factor in the accuracy and specificity of the dispersion model. Pollutant sources can be generally accounted for in three classes: point sources, line sources, and area sources. Two of these classes, line and area sources, have been discussed in earlier sections. The third, point sources, is defined as those sources which have emissions from a narrowly defined area that exceed a certain classification level, such as 100 tons of pollutant per year. Major point sources include power plants, commercial space heating units, industrial process units (boilers), and batch plants (asphalt and concrete production). The basic data source for point sources consists of air pollution emission permits submitted by businesses and industries to the local health department. An inventory of point sources and rough estimates for area and line sources are also maintained by EPA through the National Emissions Data System (NEDS). In addition to the kind of pollutant and the amount of emissions released by the point source, the dispersion model also requires input data identifying the location of the source in appropriate grid coordinates, the stack height of the source, stack diameter, stack exit velocity, and stack exit temperature.

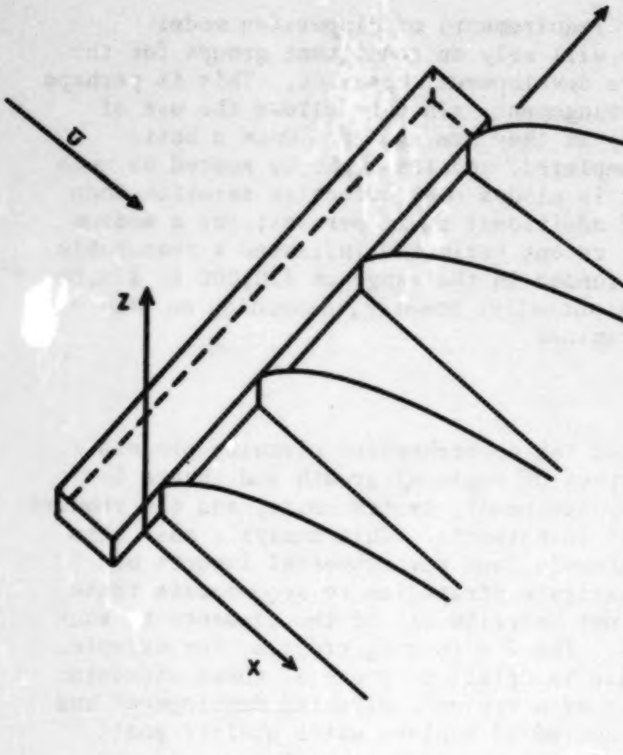
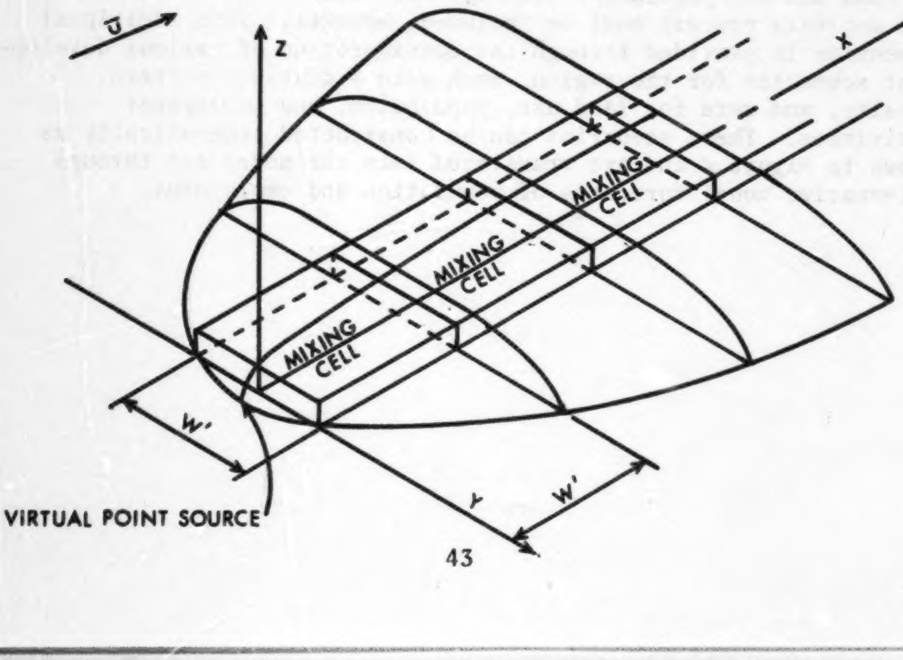


Figure 2 Gaussian Dispersion of Pollutants from an Infinite Line Source Under Crosswind Conditions

Figure 3 Gaussian Dispersion of Pollutants from a Point Source Under Parallel Wind Conditions


U
Z
X
MIXING CELL
MIXING CELL
MIXING CELL
W'
Y
W'
VIRTUAL POINT SOURCE

Model Use

Because of the technical requirements of dispersion model operation, many agencies will rely on consultant groups for the evaluation of alternative development scenarios. This is perhaps the most satisfactory arrangement, since it allows the use of specialized services only as they are needed. Once a basic evaluation program is completed, updates might be spaced as much as five years apart. It is also a cost effective solution when compared to the costs of additional staff persons; for a medium sized metropolitan area, recent estimates indicated a reasonable modeling program can be funded in the range of $20,000 to $25,000.[24] Such costs may vary substantially, however, depending on the particular case to be examined.

Plan Analysis

The plan analysis phase of the comprehensive planning process attempts to weigh the impact of regional growth and change in terms of the resulting system needs, system costs, and the requirements for public facility investments. This analysis must also determine the social, economic, and environmental impacts of growth, and it must investigate strategies to accommodate these needs. This report can not describe all of the elements to such a comprehensive analysis. The 208 funding program, for example, is intended to investigate in detail only one of these elements: the water quality impacts of a region's expected development and the public investment required to achieve water quality goals through waste treatment systems, management systems, land use controls, etc. (As noted in the Introduction, the 208 program also allows considerable flexibility in evaluating accompanying air quality impacts).

The air quality impacts associated with regional development can be evaluated using the set of land use, transportation, and air quality models described in the previous sections. In order to evaluate more precisely the sensitivity of regional air quality to land use and population alternatives, additional dimension to the analysis process must be included, however. This additional dimension is provided through the consideration of various development scenarios for the region, each with a distinct pattern, density, and rate for land use, population, and employment activities. These scenarios can be constructed schematically as shown in Figure 4 and are translated into the model set through alternative zonal forecasts of population and employment.

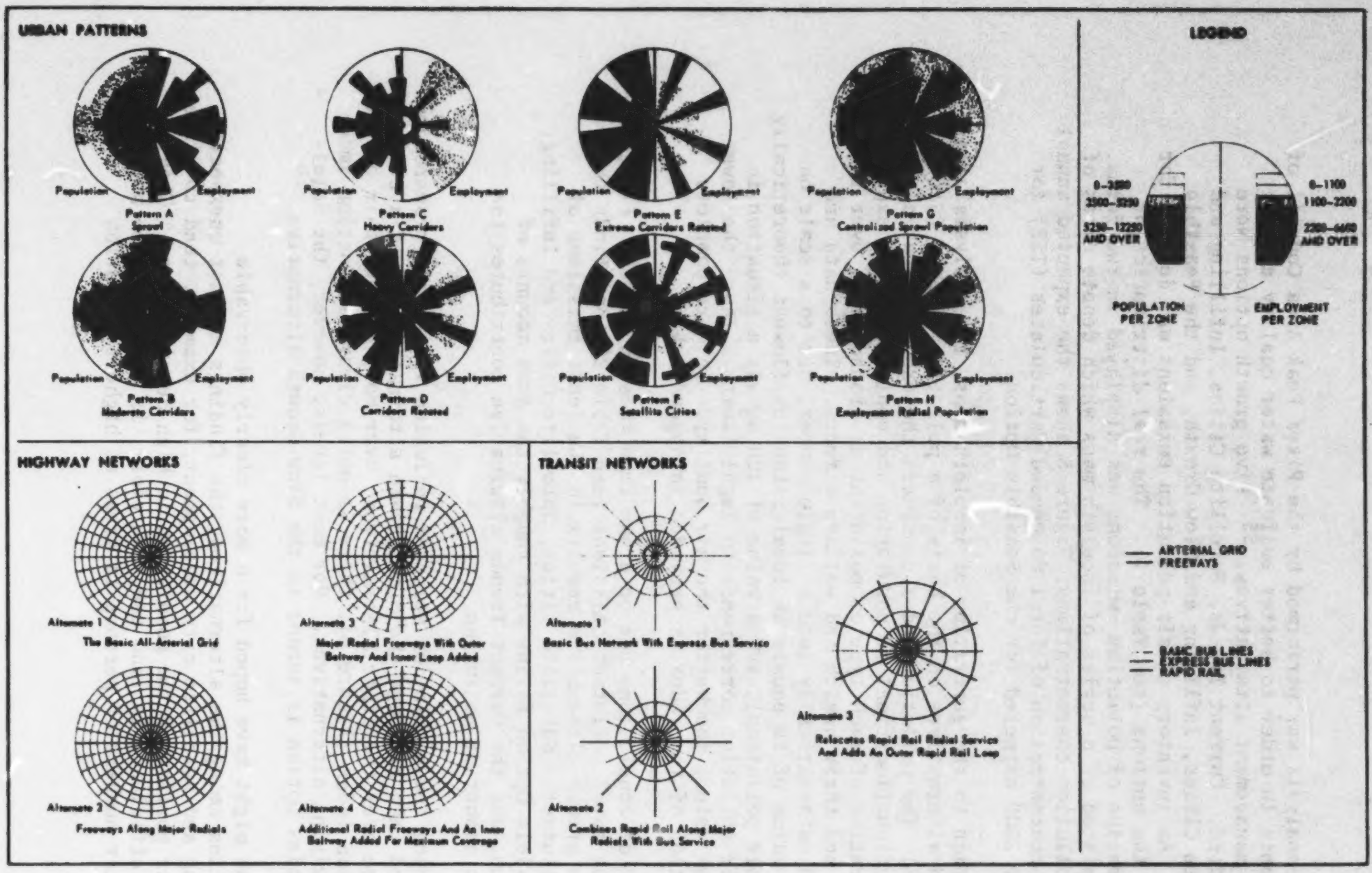

URBAN PATTERNS
Population
Employment
Pattern A
Sprawl
Pattern B
Moderate Corridors
Pattern C
Heavy Corridors
Pattern D
Corridors Rotated
Pattern E
Extreme Corridors Rotated
Pattern F
Satellite Cities
Pattern G
Centralized Sprawl Population
Pattern H
Employment Radial Population
LEGEND
0–3300
3300–5250
5250–12250
AND OVER
POPULATION
PER ZONE
0–1100
1100–2200
2200–4400
AND OVER
EMPLOYMENT
PER ZONE
HIGHWAY NETWORKS
Alternate 1
The Basic All-Arterial Grid
Alternate 2
Freeways Along Major Radials
Alternate 3
Major Radial Freeways With Outer Beltway And Inner Loop Added
Alternate 4
Additional Radial Freeways And An Inner Beltway Added For Maximum Coverage
TRANSIT NETWORKS
Alternate 1
Basic Bus Network With Express Bus Service
Alternate 2
Combines Rapid Rail Along Major Radials With Bus Service
Alternate 3
Relocates Rapid Rail Radial Service And Adds An Outer Rapid Rail Loop
ARTERIAL GRID
FREEWAYS
BASIC BUS LINES
EXPRESS BUS LINES
RAPID RAIL

Figure 4 Description of Urban Forms and Transportation System Simulation Study [26]

Such an analysis was performed by the Pikes Peak Area Council of Governments in order to better evaluate water quality and air quality management alternatives.[25] Five growth options were constructed: Current Trends, Satellite Cities, Infilling and Satellite Cities, Infilling and Slow Growth, and the Feasible Option. An inventory of air pollution emissions was derived for each of the options (see Table 1). The real distribution or concentration of pollution emissions was displayed in two forms. One consisted of a series of isopleth maps which denote areas of equal pollution concentrations; Figure 5 shows the expected annual average concentration of Total Suspended Particulates (TSP) for the year 2000 expected for the Feasible Option.

In addition to the generation of isopleth maps, the analysis also compared alternatives on the basis of a pollution index. (See Figure 6) The pollution index considers the expected spatial distribution (location) of population and employment, the expected concentration of each type of pollutant at ground level over the Region, and their health and welfare effects. These data are combined mathematically into a single number, set to a scale on which a value of 10 equals an ideal situation (lowest theoretically obtainable pollution), and a value of 100 equals a situation in which air pollution corresponds to legal limits. Thus, the lower the index value, the better the air quality. (A more complete description of the index is provided in Appendix B).

A number of conclusions can be drawn from these analyses. First, comparing total pollutant emissions (see Table 2), one finds that the slow growth alternative results in the least emissions of each pollutant. Satellite Cities, Satellite Cities and Infilling, and Feasible Option follow with roughly the same amounts of pollution, and the Current Trends alternative contributes the greatest amount of pollution.

Considering the population weighted pollution index, the researchers concluded that although the Slow Growth alternative showed a clear advantage over the other alternatives, over most of the scale of the population index (Figure 6), there is not a clear distinction among the remaining alternatives. For most levels, however, the Satellite Cities option is second to the Slow Growth alternative.[26]

While one might have hoped for a more clearly observable distinction among the alternatives, the findings are not unexpected. Infilling and satellite city development, for example, tend to place a greater portion of the population in high density areas. The greater efficiency in land use, therefore, is offset by the presence of greater numbers of persons in areas of highest pollution

TABLE 1
SUMMARY OF AIR QUALITY PROJECTIONS

GROWTH OPTION*

Emissions (Tons/Year)	1970	Current Trends	Satellite Cities	Infilling & Satellite Cities	Infilling & Slow Growth	Feasible Option
CO	232,510	34,600	31,900	33,700	26,300	28,400
HC	36,400	6,100	5,700	6,000	4,600	4,950
NO_x	12,500	58,700	58,100	58,500	41,700	57,350
PARTIC.	14,150	55,100	54,900	55,000	41,600	53,650
SO_2	1,950	62,700	62,600	62,600	42,700	64,300
Pollution Index		40.6	43.6	42.6	37.3	49.86
POPULATION AREA		25	25	25	22	20

(10 = ideal)
(100 = legal limits)

* Taken from "Air Impacts" prepared by Resource Science Inc. for Options For the Future, What Do They Mean (Colorado Springs: PPACG, 1975) p. 47.

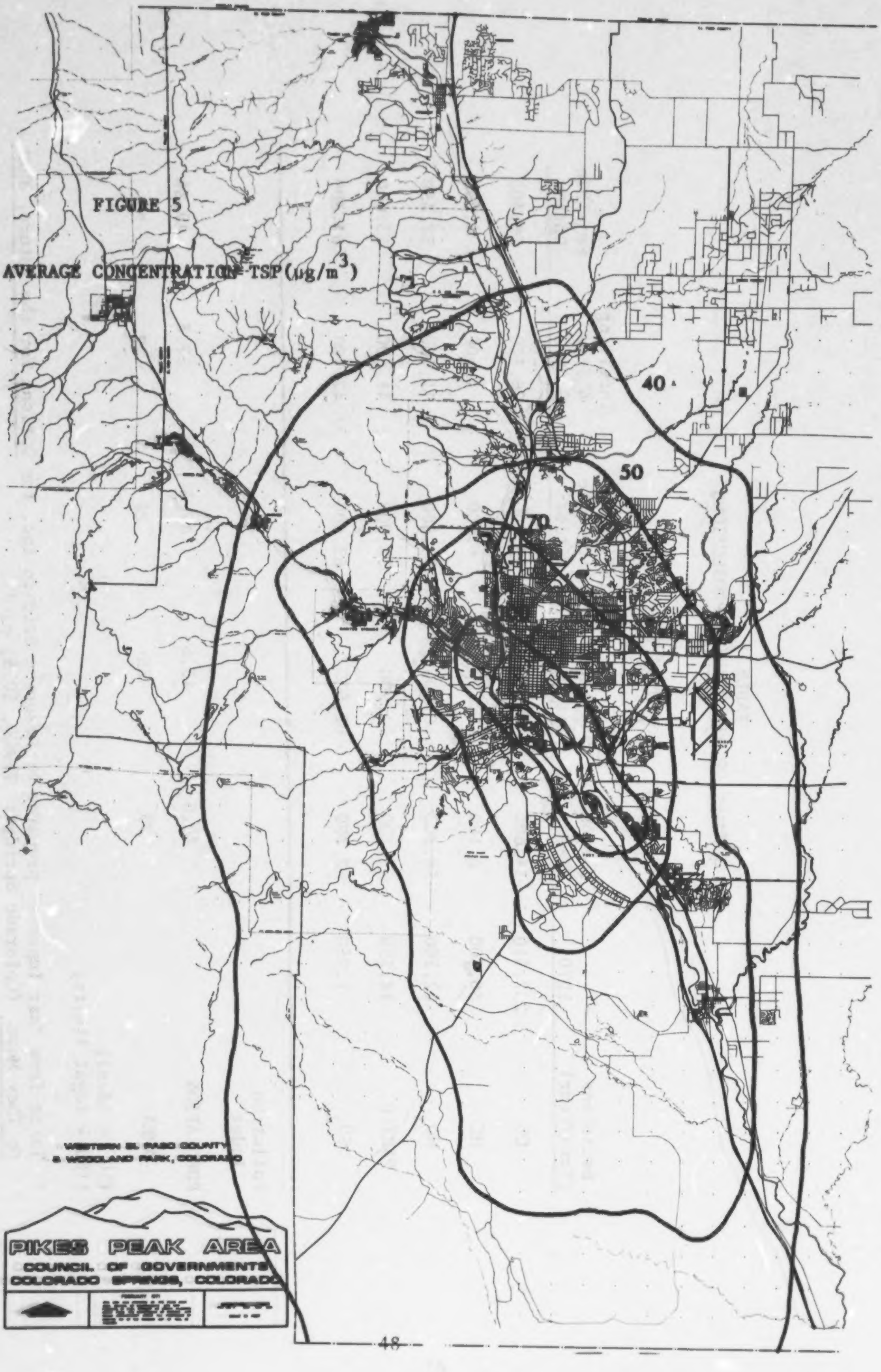


FIGURE 5

ANNUAL AVERAGE CONCENTRATION-TSP($\mu g/m^3$)

40
50
70
WESTERN EL PASO COUNTY
& WOODLAND PARK, COLORADO
PIKES PEAK AREA
COUNCIL OF GOVERNMENTS
COLORADO SPRINGS, COLORADO

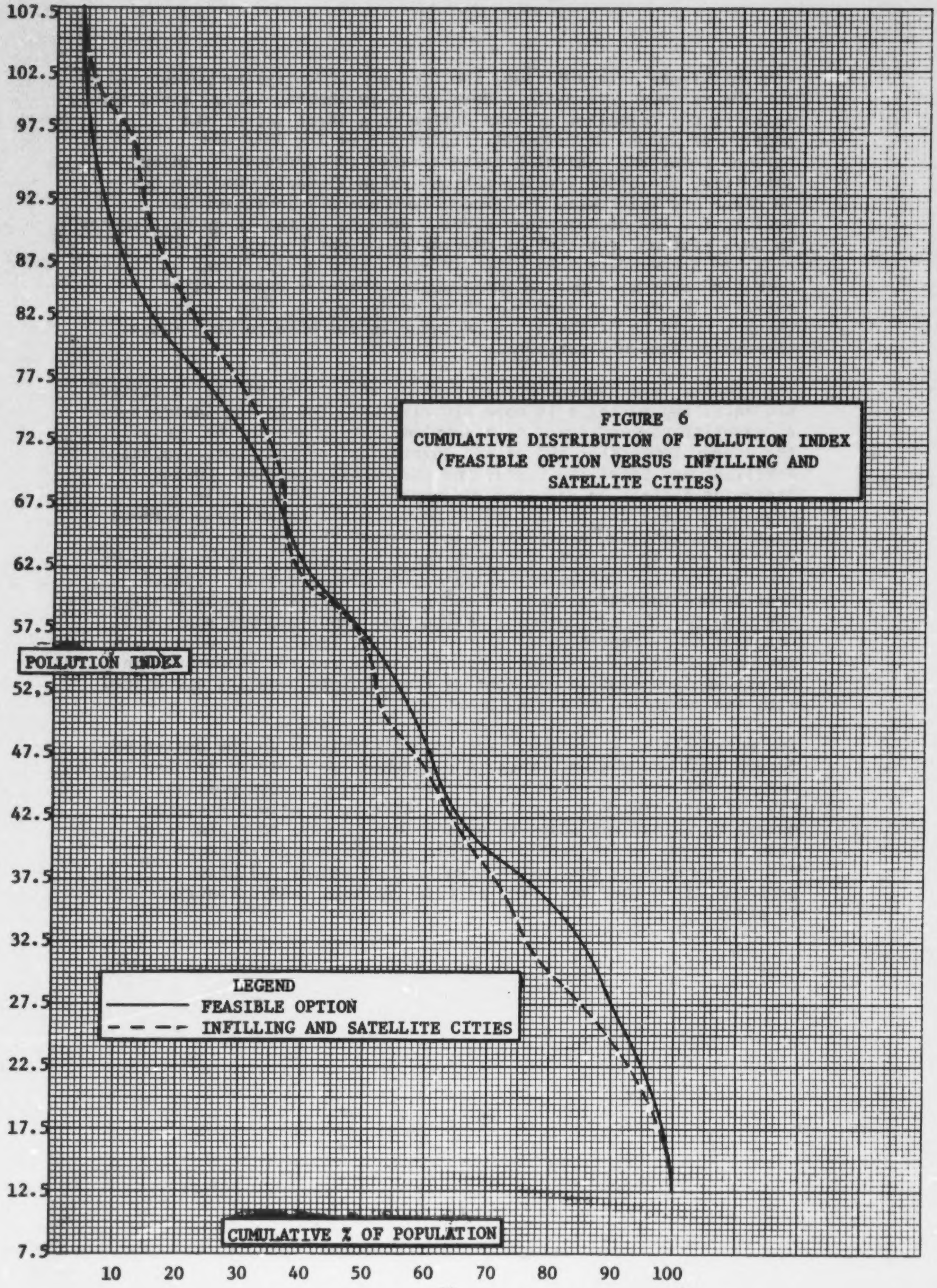


FIGURE 6
CUMULATIVE DISTRIBUTION OF POLLUTION INDEX
(FEASIBLE OPTION VERSUS INFILLING AND
SATELLITE CITIES)

46 1323
K+E 10 X 10 TO 1/2 INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

concentrations. In addition, the transportation system postulated for the various alternatives does not vary substantially, since the existing and committed systems define to a large extent the pattern of future development, regardless of the land use options selected. Existing systems refer to expressways, major arterials, and other transportation system elements that are now in place and which were designed to accommodate increases in traffic for the sectors they serve. Because of the large investments in such systems, substantial changes could not be expected in order to accommodate radically different land use patterns. Committed systems refer to improvements that are scheduled or budgeted in order to meet immediate needs; again, substantial changes would be difficult to engineer in response to long range changes in land use patterns.

The greater land use and transportation efficiency of the satellite and infilling patterns is more clearly indicated in the analysis of gasoline consumption. As a supplementary phase to the analysis, the energy impacts of two of the development options were evaluated: Infilling and Satellite Cities and the Feasible Option. Using statewide factors on gasoline consumption per vehicle mile and adjusting these factors according to highway type and neighborhood classification, the analysis indicates that the Feasible Option will consume approximately five percent more gasoline than would be the case for the Infilling and Satellite Cities option. Space heating and industrial uses of energy were estimated to be nearly the same for the two options. While this supplementary phase did not provide a comprehensive view of related impacts, it does demonstrate that a consideration of closely related phenomena can be extremely useful in documenting the multiple benefits associated with the selection of a single option.

For metropolitan areas that have some flexibility in the design of future land use systems, then, a comprehensive analysis process such as the one described here offers one of the most positive ways of maintaining air quality. In effect, it allows decision makers to adjust and adapt an area's form in ways to minimize or reduce air pollution problems. This process avoids the more disruptive actions that may be required to remedy pollution problems after they have been allowed (perhaps inadvertently) to occur.

AIR QUALITY CONTROL STRATEGIES

As the previous sections have outlined, the first step in regional air quality analysis consists of evaluating development alternatives to see if there are any growth and land use patterns that will lead to the attainment of air quality standards. If such an analysis demonstrates that development is not likely to occur in a way that will lead to compliance with air quality standards, the second stage in the analysis process involves the consideration of specific air quality control measures. Since these measures will involve the manipulation of urban systems to a much greater degree than the selection of growth alternatives, it is important to develop an analysis framework that will evaluate the relationship among systems and provide a basis for choosing among control measures.

The emphasis here, as with the rest of the report, is on the evaluation of the land use and growth consequences of pollution control measures, for these elements form the interface of air quality with water quality, transportation and other comprehensive planning issues. The evaluation of air quality impacts, as described earlier, involves the translation of changes in urban activities (auto use, industrial production,construction practices) into a set of emission rates which are distributed over the urban area using modeling techniques. The evaluation of other systems involves the utilization of facility impact criteria to assess the consequences of a particular project or control measure. These impact criteria or evaluation factors serve to identify opportunities or constraints to development. Moreover, they provide the information for an evaluation of broader policy issues, and they provide the means by which conformance to overall plan goals and objectives are assessed. (See again Figure 1 for a schematic view of this relationship between analysis and policies).

Each of these control measures will have a measurable impact on the development of urban systems. This impact, in general, can be traced to either of two factors: (1) changes in the emission rates of a process, activity, or land use; or (2) changes in the level or density of activity. Controls of auto pollution, for example, can focus on reducing the emission characteristics of autos, in reducing the use (VMT) of autos, or in redirecting traffic to lower density corridors. The determination of the reduction in pollution concentrations must, therefore, derive from estimates of changes in emission rates or levels of activity. Obviously, the method for determining these reductions will vary depending on which of the strategies are being considered; the air pollution impact of a grading ordinance intended to control erosion associated with land development will be constructed in a much different fashion than the method used to estimate pollution reductions from an automotive inspection/maintenance program. A description of an appropriate methodology for each of the possible control measures is beyond the scope of this report. Once estimates of pollution reduction are obtained, however, these changes are subtracted from the emission inventories of point, line, or area sources, and their impacts on ambient concentrations are evaluated using the modeling procedures described in the previous sections of this report.

Table 2 provides a list of strategies that are applicable to urban areas for controlling pollution problems. While not an exhaustive list, it does attempt to outline those control strategies that might be of regional concern.

In addition to the expected impact on ambient air quality, control strategies such as those listed in Table 2 will undoubtedly have an impact on related urban systems. Table 3 lists in the first column regional impacts typically considered in a comprehensive planning process. Table 3 also lists criteria for plan evaluation; these criteria allow for the quantification of economic, social, and environmental impacts of alternative development patterns, alternative air quality control strategies, and alternative urban systems. Information sources relevant to the quantification of impacts are summarized in the second column of Table 3, "Data Sources."

Not all control strategies, of course, will have impacts on other systems. Where strategies can be applied at a regional level, however, other impacts can often be traced. Particularly for those strategies that deal with land use controls (zoning controls, development controls), transportation measures (transit development), or housing development (higher densities), social or related system impacts are readily identifiable. A comprehensive transit development program, for example, may include zoning incentives for encouraging residential or employment development along major transit corridors or at the intersection of transit routes; such a zoning incentive program might imply higher building densities, which in turn would alter the system demands for handling waste water. Similarly, strategies aimed at reducing the use of autos or making their use more difficult and costly may have the effect of encouraging development which reduce travel demands and decrease pressures towards urban sprawl.

TABLE 2
STRATEGIES FOR AIR POLLUTION CONTROL

Provide Alternatives to Private Auto Travel
- Increase transit capacity
- Attract transit ridership
- Increase para transit use
- Encourage pedestrian and bicycle modes

Improve Vehicular Flow
- Increase vehicle throughput
- Improve urban goods movement
- Reduce peak hour traffic columes
- Divert traffic from high density areas

Reduce Urban Auto Use
- Increase auto occupancy
- Increase cost of auto use
- Restrict zonal access
- Institute parking management plan

Reduce Urban Travel Demand
- Encourage communications substitutes
- Encourage decentralized nodal development
- Encourage four-day work week

Reduce Vehicular Emissions
- Institute front range inspection/maintenance program
- Institute State standards for mobile emission
- Improve street maintenance, pave streets
- Mandate no-lead gas for all vehicles
- Retrofit cars with particulate traps
- Tax cars according to emission generated

Reduce Gasoline Consumption
- Develop urban minicar systems
- Introduce non-petroleum based vehicles
- Tax cars according to gas consumption

Develop More Transportation Efficient Land Use Systems
- Develop employment centers within existing municipalities
- Encourage development of multi-use activity centers
- Purchase or control critical open space areas
- Redevelop, revitalize urban core areas

Develop More Efficient Housing Patterns
- Encourage appropriately located high density development
- Encourage revitalization of older neighborhoods
- Encourage greater range of opportunities for low and middle income groups, e.g., more appropriately located with respect to employment opportunities
- Develop codes for efficient housing production, e.g., solar homes

TABLE 2 (Con't.)
STRATEGIES FOR AIR POLLUTION CONTROL

Control Developing Areas of Region
- Institute erosion controls on undeveloped urban lands
- Institute uniform grading requirements within Region
- Develop taxing program consistent with development goals

Develop More Stringent Controls of Point Sources
- Restructure utility pricing
- Increase emission control requirements
- Schedule phase out of most polluting industries
- Develop site criteria for facility location

The third column in Table 3, "Data Cost", categorizes the costs of utilizing various data sources. These costs are estimated relative to standard planning model products. In the transportation planning process, for example, vehicle miles of travel, accessibility indices, and specific link volumes will be compiled as part of the transportation planning process, so the cost of these data is low. Moderate costs are indicated for data that may be derived from existing files, although some effort would be required to compile data in a form useful for evaluation purposes. A high cost is indicated for data that would require field survey work or the preparation of plans in more detail than needed for long range planning purposes. Time and financial constraints may make it necessary to ignore some of the listed data sources. Development of a sophisticated public cost evaluation model, for example, could cost in the range of $200,000 to $300,000.[27]

The fourth column in Table 3 lists specifically those criteria that would be used to evaluate and compare alternative plans. These criteria include demand data (water use associated with growth controls), costs (highway improvement estimates), and qualitative measures (changes in landscape qualities). Each of these criteria can then be weighed in relation to particular system characteristics (the demand for water in relation to the projected raw water supplies) or in terms of overall development constraints (a transit improvement in relation to a city's total capital improvement budget or bonding capacity). The principal air quality criteria for evaluation of control measures are the national ambient air quality standards; if a control measure or a combination of strategies allow these standards to be attained and maintained, they can be judged to be effective.

In order to further describe these evaluation criteria, the last column in Table 3 categorizes the criteria with respect to scale, sensitivity, and reliability.

The scale of the evaluation criterion is categorized as regional, mixed, or local. Regional scale refers to criterian which describe impacts on the Region as a whole. Local scale refers to criteria that evaluate a small area, such as a neighborhood or specific site. Mixed scale refers to criteria describing impacts which are localized, but also exhibit spill-over effects perceived outside the area of primary impact.

Sensitivity indicates the degree of variation expected for a specific criterion, among the various air quality strategies. Impacts shown to have a high sensitivity are expected to highly dependent on characteristics of the air quality strategies; criteria shown to have low sensitivity are more strongly related to urbanization characteristics other than air quality strategies.

TABLE 3
REGIONAL IMPACT ANALYSES

Regional Impacts	Source Data	Data Cost	Criteria	Evaluation of Criteria		
				Scale	Sensitivity	Reliability
Air Quality Impacts						
CO	Link volumes and speed	Low	Ambient concentrations	Regional	High	Moderate
Particulates	Meterological conditions	Low	Pollution emissions by land use, industry type	Regional	High	Moderate
NO_x	Point source inventory	Moderate		Regional	High	Moderate
Hydrocarbons	Area source characteristics	Moderate	Pollution emissions by auto year, speed, altitude	Regional	High	Moderate
Ozone		High		Regional	High	Low
SO_2	Transit system characteristics	Low		Regional	High	Moderate
Water Use						
Consumptive Demand for Water	Regional urbanization characteristics	Moderate	Regional use data, population, and consumptive projections	Regional	Low	High
Water System Requirements	Growth characteristics by sector	Moderate	System demand projections, capital equipment purchase schedules	Regional	Moderate	Moderate
Water Quality Control						
- Point Sources						
Demand for Waste Treatment Units	Regional urbanization	High	Stream pollution concentrations, capital cost projections	Regional	Low	High
Demand for Collector, Outfall Extensions	Regional urbanization characteristics	High	Zonal projections, collector capacity, replacement, expansion costs	Mixed	Moderate	Moderate
- Non Point Sources						
Change in Runoff, Sediment Loading	Storm flow characteristics, percolation rates, soil erosion rates	High	Amount of impervious surfaces, stream pollution concentrations	Mixed	Low	Moderate
Change in Stream Volume	Storm flow characteristics, percolation rates, climate factors	Moderate	Flow readings, annual rainfall	Regional	Low	High

TABLE 3 (Con't.)
REGIONAL IMPACT ANALYSES

Regional Impacts	Source Data	Data Cost	Criteria	Evaluation of Criteria Scale	 Sensitivity	 Reliability
- Non Point Sources (Con't.)						
Change in Floodwater Absorption Capacity	Regional urbanization characteristics, floodplain, project design	High	Identification of critical areas, affected land uses	Regional	Low	Moderate
Change in Groundwater, Aquifer Recharge Capacity	Urbanization characteristics, aquifer system characteristics	High	Change in recharge rates for specific aquifers	Regional	Low	Moderate
Change in Soil Erosion Rates	Soil loss equations, vegetative cover, climate factors	Moderate	Changes in soil cover, slope characteristics, impervious cover	Local	Low	High
Energy Use						
Gasoline Consumption	State sales tax receipts	Low	Selected annual costs	Regional	High	High
Natural Gas, Fuel Oil Use	Utility system sales	Low	Selected annual costs	Regional	High	High
Coal Use	Utility system vouchers, coal distributer sales	Moderate	Selected annual sales, purchases	Regional	High	High
Transportation System Costs						
Roadway Construction	New construction & widening mileage, design characteristics	Low	Total costs, 1976-2000, selected annual costs	Regional	High	High
Transit Terminal Constr. Vehicle Acquisition	Number of vehicles by type, system characteristics	Low	Total costs, 1976-2000, selected annual costs	Regional	High	High
Roadway Maintenance, Traffic Control, Administration	VMT, route mileage, system characteristics	Low	Total costs, 1976-2000, selected annual costs	Regional	High	High
Noise Pollution						
Sonic Disturbance to Residential Areas, Hospitals, Etc.	Link volumes and speeds, transit characteristics, specific site characteristics	Low	Noise levels by resident population	Local	Moderate	Moderate
Sonic Disturbance to Wildlife, Recreational areas		Low	Noise levels by land use	Local	Moderate	Moderate

TABLE 3 (Con't.)
REGIONAL IMPACT ANALYSES

Regional Impacts	Source Data	Data Cost	Criteria	Evaluation of Criteria Scale	 Sensitivity	 Reliability
Private Sector Costs & Benefits						
Land Costs	Site development standards, accessibility indices	Low	Selected land sale prices	Mixed	Moderate	Low
Land Development Costs	Design standards, site characteristics	Moderate	Selected sale, rental prices, industry survey indices	Mixed	Moderate	Moderate
Property/Vehicle Relationship	Accessibility indices	Low	Changes in accessibility for specific areas	Regional	Moderate	Low
Tax Rate Changes	Property assessments, user charges	Low	Changes in tax rates for gasoline, property, pollution emissions, etc.	Regional	Moderate	High
Social Impacts						
Mobility by Private Auto	Accessibility indices by employment and commercial centers, public facilities	Moderate	Changes in accessibility by population group	Regional	High	Moderate
Mobility by Public Transit	Accessibility indices by employment and commercial centers, public facilities	Moderate	Changes in accessibility by population group	Mixed	High	Moderate
Vehicular Conflicts with Pedestrians, Cyclists	Link characteristics, design features	Moderate	Changes in link volume, qualitative impact assessment	Local	Moderate	Low
Accident and Health Hazard	Vehicle miles by design class, population exposure to pollutants	Moderate	Changes in morbidity, mortality by disease, accident file	Regional	High	Moderate
Displacement of Residential & Commercial Properties	New construction & widening mileage, urban renewal project designs	High	Identification and valuation of affected sites	Mixed	Moderate	Moderate

TABLE 3 (Con't.)
REGIONAL IMPACT ANALYSES

Regional Impacts	Source Data	Data Cost	Criteria	Evaluation of Criteria		
				Scale	Sensitivity	Reliability
Social Impacts (Con't.)						
Aesthetics						
Changes in Natural Landscape Qualities	Regional urbanization characteristics	High	Qualitative impact analysis	**Mixed**	**Moderate**	**Low**
Changes in Scale of Development	Roadway construction, site design characteristics, historic area designations	High		**Mixed**	**Moderate**	**Low**
Changes in View Corridors, Landmarks	Roadway construction, site design characteristics, historic area designations	High		**Mixed**	**Moderate**	**Low**

Reliability is an indication of the precision, accuracy, or confidence with which a criterion can be predicted. It is assumed that there are no gross errors in the development projections underlying the overall modeling process. The validity of the development projections must be verified by observing actual development trends.

Through a systematic evaluation of air quality control measures and their impacts, there can be some assurance that planning elements have been properly integrated. Again, the form which such an analysis process takes will vary substantially from region to region. The following chapters, however, attempt to describe greater detail the form of two of the more troublesome analyses problems: social and economic impacts. These chapters provide some description of the nature of those problems, and there is an attempt to define in general terms the appropriate direction in undertaking more detailed analyses. Appendix D also provides an illustration of a regional impact analysis for one control measure.

EVALUATION OF SOCIAL CONSEQUENCES

Air quality control strategies in most metropolitan areas will in some way affect our life-style, our pocket books, and the living environment which surrounds us. To the extent these effects can be documented, they provide additional depth to the analyses of air quality strategies. This depth provides an additional set of criteria which can be used to compare strategies and offers material which can provide more complete documentation or justification for selected air quality strategies.

Because the evaluation of social impacts must deal to a large degree with qualitative variables (aesthetic, life-style changes), one can not hope for the same degree of precision that is allowed in the comparison of costs, for example. The analysis of social impacts will need to rely much more on a descriptive evaluation where quantitative measures are not available. Table 4 provides an example of the form such an analysis might take. It includes criteria from the previous chapter and lists additional social or "psychic costs". These criteria are applied to one specific control measure, an auto inspection/maintenance program.

Impacts are briefly described and categorized in one of three general categories which describe the net effect of the control measure. Such a framework could be expanded to include a more precise scale, for example, by rating each factor with points from one to ten. A more precise scale, while certainly preferable, also requires a more sophisticated weighting system to distinguish among various scores or ratings. However, such an approach is not to be discouraged, particularly where the local citizenry have made it clear where their values are focused or which issues are of most importance to them.

Alternatively, the number of positive or negative reponses may simply be summed to give straight forward indication of the expected social impacts. Again, appropriate descriptive summaries of the social impacts as well as the inclusion of quantitative measures where they exist e.g., expected increase in noise pollution in decibels, can do much to bolster the analysis.

Social Issues

Regardless of the sophistication of the analysis process, at some point alternative control measures will need to be exposed to the strutiny of public opinion and political judgements. Public issues, in fact, may be of greater consequence in the selection or

TABLE 4
Social Impact Assessment

Program; auto inspection/maintenance

Operation: annual exhaust gas analysis of autos beginning with model year 1977 to ensure compliance with manufactures specifications

Criteria	Description of Impact	Net Effect + positive 0 no effect - negative effect
Cost	Minimum cost $5 for inspection Average cost $50 for tune up Maximum cost $500 - $1,000 for major engine overhaul	+
Income Class Effect	Low income families tend to have older cars that will be more difficult and expensive to maintain	-
Noise Pollution	Minor reduction from detection of faulty mufflers	o
Auto Mobility	Minor inconvenience for inspection scheduling	o
Transit Mobility	Slight increase to degree inoperable cars result in greater utilization of transit	o
Accident & Health Hazard	Reduction of health hazard associated with pollution; 10-30% reduction in regional levels of auto pollution	++
Residential or Commercial Displacement	Slight encouragement to expansion of auto repair sector	o
Aesthetics	Visual emissions from autos will be controlled through program	+
Psychic costs		
privacy		
comfort	Auto tune up will improve performance of auto, comfort of use	+
security		o
status		o
possession	Restricts auto ownership to ones with operable pollution controls	-
responsiblity	Increases time and effort needed to maintain auto	-
authoritv	Implies greater public control of auto use	-

acceptance of control measures than the cool dispassion of an analysis procedure such as the one outlined in Table 4. While there certainly is no key to the successful handling of public issues, a more detailed discussion will perhaps provide some insight into the shape such issues will take, methods for assessing public response, and ways to search for fairness in dealing with public issues.

The basic social response to air pollution is linked fundamentally to a set of economic factors. These factors have been described in the concept of common property resources (sometimes formulated in terms of the "Tragedy of the Commons").[28] Common property resources are those that for a variety of reasons are not held in private ownership but are in some sense collectively held; that is, they are not under any person's or institution's managerial control. Important examples of these resources are water bodies, the air mantle, and various other ecological systems.

In a frontier society such as the one that characterized this country until only recent decades, the dispersed populations and low levels of economic activity did not generally tax the capacity of air and water to assimilate wastes. These common property resources were in such abundance that they come very close to the economist's definition of free goods. But as population, urbanization, and economic activity accelerated, what were once plentiful environmental resources became increasingly scarce. Nevertheless, the nation continued to treat these resources as if they were free goods.

In most circumstances the price system provides incentives for economizing on scarce resources. Goods which require scarce resources in large amounts for their production or sale are expensive compared to those that do not, so the consumption or production of these goods is discouraged. Since common property resources do not command a price, there is no similar disincentive to minimize the discharge of pollutants into the air. The private market system encourages their overuse rather than their conservation.

The problem is not that the price system does not work - it works with marvelous efficiency. When the price of water and air are fixed essentially at zero, thousands of firms and millions of individuals bend their resources to use these cheap resources. Thus, what is nominally rational social or market system behavior creates a set of pollution problems which are socially and physically unacceptable.

The problem arises primarily because the institutions of private property and exchange which we use for determining the value of resources and providing incentives for their efficient allocation do not function for environmental resources. There is, in fact, a social value to air and water resources that is not reflected in the price system.

A corollary of this concept is that in cases where there is no charge or payment associated with the use of the air, there is no incentive for an individual to incur costs for pollution abatement. Since an individual's decision to buy an emission control device or to carefully maintain his car, for example, has virtually no effect on regional pollution levels, it is rational for the individual to not incur costs of this nature, since he will receive no perceptible benefits from his expenditure. Individual initiative, while potentially a powerful force, can not be expected to operate when such action is not consistent with basic economic facts.

The basic problem, therefore, in designing programs that are workable is two-fold: one is to create a framework for collective action and collective management that accurately defines the social cost of air and water pollution; the second is to develop the proper social and financial incentives for the allocation and management of air resources.

The social response of the citizenry to the problems of environmental management is also shaped by other cultural and institutional phenomena. Because of the complex nature of the issues, because of the unprecedented scale of the problem, or perhaps because of the mass media, there is commonly a disassociation between real problems objectively posed by situations and often formulated by specialists, on the one hand, and what public opinion generally considers to be a problem, on the other. For a society such as ours that has only recently passed from its frontier era, problems have traditionally been smaller, more down-to-earth, or more easily agreed upon. Secondly, the rapid acceleration of technology and commerce - of history, in fact - no longer allows for the deliberate, progressive working out of details characteristic of traditional societies.

In our technological society, things change faster than social systems can accommodate. What is required is a dynamic view of the future. Instead of creating a fixed, unchanging, and stable future, we must now absorb the dimension of change as a major element of our lives. Goals we expect from the future are now a moving target, demanding constant adjustments in the way we perceive the future. The future can only take shape as we live and advance toward it.

Such a profound and rapid change in the basic social and cultural requisites demanded by a technological economy account in large part for the seeming reticence of public groups to accept the concept of environmental management. Public leaders, more than other elements of the citizenry, seemed to be particularly inflexible. A recent Harris survey found that 80 percent of the Americans polled felt that the energy shortage is today a "serious" problem; only two percent of political leaders think people view the energy shortage as being "serious". In fact, leaders moved in 1976 to an even lower estimate of public concern over energy than they had in 1975. Perhaps because political leaders are thought of and think of themselves as "pillars" of the community they are peculiarly handicapped in roles that require a keen view of the future rather than a strong sense of the past.

While this analysis may be useful in understanding the social dilemma posed in confronting air pollution problems, it does not necessarily provide the insight necessary in constructing a socially acceptable or equitable set of control strategies. The most positive approach would be to focus on the development of the necessary incentives to manage air resources. This approach differs from the more widely applied regulatory approach which sets fixed limits for the reduction of pollution. Once the prescribed limit has been reached there is no further incentive to reduce pollution. Instead, there is a positive incentive not to do so, since additional reductions imply greater costs.

Economic strategists find greater practical value in a pollution charge or tax approach. Such a tax requires the firm or the individual to pay for the pollution he has not removed, and would automatically force each decision maker to reckon the social cost of his activities. In addition, it provides a greater incentive to reduce pollution, since costs are not related to the achievement of a regulatory standard but to the pollution that is not controlled.

One application of such an approach would be the application of a "smog tax" for the control of automotive pollution. One version of this tax would require cars to be tested periodically and assigned a smog rating. A tax related to the amount of gasoline consumed by the automobile would be fixed according to the pollution rating of the automobile; that is, the cars that polluted most would pay the most for the gasoline they use. Such a tax encourages the consumer to consider a number of alternatives: he can have his engine tuned to reduce pollution and lower the tax category of the automobile; he can drive fewer miles and reduce the tax paid through the gasoline surcharge; or he can select a new car with better performance characteristics, thus providing an incentive for manufacturers to design more efficient engines.

Multiple Benefits

Beyond the design of an appropriate incentive scheme to encourage pollution reduction, another important criterion that should be used to test the social feasibility of plans is the degree to which air quality strategies achieve other land use, transportation, and environmental goals. That is, air quality strategies which are of positive value in achieving other planning goals have a much broader base from which to draw support. For example, a properly applied car pooling program will not only reduce the contribution of cars to air pollution, but will reduce traffic congestion and conserve energy resources. Similarly, grading ordinances are designed to reduce both the wind and water erosion of soils associated with land development. Such an approach underscores the importance of a comprehensive approach to the air quality planning problem; in practical terms, it is a prerequisite in the evaluation of control strategies.

Equity Issues

The costs and benefits associated with cleaner air will not be distributed evenly. Those that live in rural areas, for example, already enjoy relatively clean air, but they will have to pay higher prices for automobiles, electricity, and other goods in order to pay the expenses of reducing air pollution elsewhere. On the other hand, large electrical power generating stations may be located far from the urban area they are intended to serve and "export" urban pollution to areas which receive virtually no long term benefit from the stations.

Another critical social issue is the income distribution effects of air quality strategies. Lower income families are more likely to have older cars which may be difficult or impossible to maintain to stringent emission standards. The cost impact of a retrofit program would thus accrue to the segment of the population least able to afford it. Similarly, lower income families are more likely to live in homes that are thermally inefficient and would pay a disproportionate share of the costs in controlling the air pollution impacts of home heating.

While the impact of control strategies will vary according to the social characteristics of each community and the severity of the pollution problem, it does not appear likely that reasonable air quality goals will drastically alter the distribution of income. Costs and benefits, while not equally shared, will be widely distributed. However, these considerations do underscore the importance of selecting or designing efficient control strategies so as to minimize the costs of achieving air quality goals. They also point to the importance of financial incentives as a means of soliciting the participation of a larger segment of the population. Loan guarantees, tax write-offs, restructured utility pricing, and improvement assessment policies are all examples of financial tools that can do much to encourage the participation of the citizenry in air quality improvement programs.

Public Opinion Assessment

The preceding discussion has centered on the social response to environmental controls and the critical factors that affect the citizenry. As a conclusion, some focus on the methods of systematically assessing public views should be offered.

As we have seen, one of the most appropriate measures of social impact is cost. Where resources permit, the costs of alternative strategies should be correlated with income characteristics of the persons affected, the size of the firm, or other characteristics which compare the incidence of control costs with the ability of individuals or institutions to absorb these costs.

Another assessment tool equally familiar to planning agencies is the use of advisory committees, citizen groups, public hearings, and other public forums to solicit comments and reactions to some set of alternatives. The citizen participation element in the air quality planning program is a critical element, in fact, for it provides not only the opportunity to better inform and educate the citizenry with regard to pollution problems, but it provides the most constructive opportunity to develop a constituency that will support local efforts to institute air quality control measures. Public acceptability of control strategies can only be developed through the involvement and participation of the citizenry. Equally important, the citizen participation element provides valuable "feedback" to planners and elected officials in designing control strategies.

Though vitally important, citizen participation programs are also beset with a familiar set of problems, and other kinds of public assessments may be useful. An additional tool is the use of the random survey to solicit responses on a number of specific air quality issues or programs. Such a technique offers the possibility of selecting a representative sample from the community, and it allows the researcher to pose the same straight - forward questions to a large number of individuals. If mailed to households, it also tends to be more convenient than attending public meetings, since it allows the respondent to complete the questionnaire as his schedule allows. While this survey technique also has a number of limitations, if properly applied it can do much to provide greater balance in the evaluation of social issues.

Obviously, no single tool can single-handedly assess the social impact of air quality strategies. Nor do social criteria alone define the set of control strategies most appropriate for a given region. However, the consideration of social issues is an indispensable element in the analysis of air quality strategies, and they bear heavily on the success or failure of an implementation program. Every effort should be made, therefore, to inform the citizenry of the critical issues, to discuss with them the alternatives available for controlling air pollution problems, and to solicit their feelings regarding the appropriateness and feasibility of alternative strategies. While such a program cannot guarantee the open and wholehearted response of the citizenry, it does provide the proper framework.

EVALUATION OF ECONOMIC CONSEQUENCES

The evaluation of the economic impacts of air quality strategies is undoubtedly one of the crucial elements of the planning process. Under severe conditions, air quality constraints may limit the location or scale of growth, they may place severe limitations on the economic viability of some polluting industries, or they may constrain the capital improvement capabilities of local governments. On the other hand, if the air quality constraints to regional development are anticipated with reasonable foresight there exist a number of alternatives which can accommodate air quality criteria and still satisfy economic goals for the region. Scheduled improvements in automobile technologies and strict standards for new point sources of pollution will offer many regions flexibility in designing strategies that, if properly applied, will mitigate the air pollution impacts of development without serious economic consequences.

Nevertheless, careful attention must be directed to the economic consequences in selecting a set of strategies. This chapter will outline an appropriate methodology for analyzing air quality strategies. However, the evaluation of each control option is a difficult matter when the technology concerning them is complex, and in most cases represents a complete study in itself. Instead, this chapter will attempt to outline the criteria or framework that will be most relevant to the evaluation of control strategies.

Cost-Benefit Matrix

Costs associated with the development of air quality control strategies are generally easier to determine and compare than more qualititative social impact variables. Other constraints in the form of research and data acquisition costs will limit the scope of the economic impact analysis, however. It should also be pointed out at the outset that the evaluation of impacts must consider benefits associated with control strategies as well as more readily identifiable costs. The pollution control industry, for example, is now a multi-million dollar industry and provides jobs to thousands of persons. Shifts to less polluting and less energy intensive kinds of products and processes will be cheaper for the consumer and create greater numbers of jobs than large scale, capital intensive projects such as nuclear power plants, or 1,000 kilowatt coal fired generators. Transportation system improvements for pollution reduction may often imply greater system efficiency and, thus, greater convenience and service to the individual. While it may be difficult to relate the cost of additional pollution control equipment on a power plant (and the accompanying rise in utility rates) to the benefits accruing to the manufacturers of such equipment nationwide, such a perspective, even in a narrative form, is important in providing a balanced view of control strategies. Similiarly, it may be impractical to construct an analysis to determine the expected reductions in morbidity or mortality and the resulting decreases in health care costs for each control strategy of each region, yet such a consideration is fundamental to the development of an air quality control program. Research is continuing in the health field, and the EPA or the National Technical Information Service would be useful sources of recent studies documenting the health consequences of air pollution; in as much as pollution effects are generally the same regardless of their location, such research findings can be useful as documentation for most air quality maintenance plans.

A framework for analyzing the cost impact of control strategies is presented in Tables 5 and 6. It is constructed as a matrix analysis in order to consider both the costs and benefits of control strategies and their incidence; that is, we need to be concerned with not only what is paid for control, but who pays it. Table 5 provides one-half of this matrix and outlines the range of costs and benefits that would be appropriate for consideration in evaluating strategies. Table 6 provides the remainder of the matrix and categories the ways in which costs and benefits may be distributed. These categories include geographic, income, and size variables that can be applied to determine what sector or what individuals are most affected. The analysis attempts to determine, therefore, not only if costs or benefits are reasonable, but whether or not they are fair in their application.

Obviously, more complex microeconomic analyses could be constructed from the outline provided here. A control strategy affecting industry, for example, might want to consider variables such as sales, prices, profits, investment potential, industry dislocation, employment, and community impacts as they relate to particular control measures. The costs of such analyses are not trivial, however. As pointed out earlier in the report, a public cost evaluation model also implies a major commitment for all but the largest metropolitan areas. In general, however, analyses can be scaled to the strategy being considered, and that information of most direct interest to decision makers can be readily attained. Table 7 provided an economic summary of an auto inspection/maintenance that could provide sufficient information in completing the evaluation of the program. It should be pointed out, however, that the detailed analysis of an auto inspection/maintenance program and its comparison with other automotive control techniques is not a simple analysis. Automotive Testing Laboratories prepared for the Colorado Department of Health a seven volume analysis of emission control programs for vehicles operating at high altitudes.[29]

TABLE 5

COST BENEFIT DETERMINATION

Public Sector Costs

- **Planning System Development**
- **Administration**
  - review
  - regulation, e.g., indirect source controls, zoning controls
  - enforcement, e.g., zoning and building code enforcement
- **Operations**
  - e.g., carpool, vanpool, street sweeping program, parking management
- **Capital Improvement - Project Budget**
  - street-highway improvements
  - public transit improvements
  - intrastructure development
  - special facilities
- **Utility Costs**
  - pollution control of power plants
  - development, administration of conservation strategies
  - public education materials

Private Sector Costs

- **Industry Costs**
  - reporting, administration
  - purchase, operation of new equipment or new processes
  - program operation, e.g., vanpool system for employees
  - land costs
  - changes in demand for product
- **Retail Service Sector Costs**
  - administration
  - operations
  - capital improvements
  - land costs
  - changes in demand for goods or services
- **Consumer Costs**
  - Auto operation
    - operation
    - maintenance
    - storage (parking)
    - purchase price

TABLE 5 (Con't.)

COST BENEFIT DETERMINATION*

- **Land Costs**
  - **land use controls**
  - **accessibility factors**
  - **land use conflicts**
- **Housing Costs**
  - **purchase price**
  - **home maintenance, rehab costs**
  - **operation (utility costs)**
  - **land use conflicts**
- **Other Goods and Services**
  - **energy intensive products**
  - **"pollution intensive" products**
  - **changes in level or costs of services**
  - **changes in demand for goods or services, e.g., health care services**

Employment Opportunities

- jobs for particular sector threatened by industry dislocation, etc.
- job potential expanded for pollution control sectors
- access to jobs affected by transportation strategies

Health Benefits

- reductions in morbidity
- reductions in mortality
- reductions in work absences
- increased physical abilities, opportunities for recreational activities
- reductions in health maintenance costs

*Note: Care must be taken in summing measures to ensure that costs or benefits are not counted twice. For example, if pollution controls add to utility system costs, they should not be counted again as increased costs to consumers in the form of increased utility bills. Similarly, increased industry costs might also be reflected in increased consumer prices; again, costs can only be counted once.

TABLE 6

COST INCIDENCE

Public Sector Costs

- local
- regional
- state
- federal
- mixed

Private Sector Costs

- Industry Costs
  - industry-wide
  - location specific, e.g., only for industry sector in non attainment area
  - process specific, e.g., only for coal-fired operations
  - size related, e.g., only 100 ton sources
- Retail-Service Sector Costs
  - sector-wide
  - location specific
  - size specific
  - product specific
- Consumer Costs
  - Income Group Incidence
    - equal for all groups
    - increasing costs with increasing income
    - decreasing costs with increasing income
  - Neighborhood Incidence
    - greater costs or benefits for central city
    - greater costs or benefits for fringe or ring
    - greater costs or benefits for suburbia
  - Regional Incidence
    - greater costs or benefits for all jurisdictions
    - greater costs or benefits for specific areas
    - greater costs or benefits for region compared with State

These studies, along with more recent updates by the Colorado Department of Health, [30] Air Pollution Control Commission and the Colorado Department of Health, conclude that a 10 to 15 percent reduction in carbon monoxide emissions can be realized through a program requiring yearly maintenance. This maintenance would fall within normal tune-up operations and would range in cost from $35.00 to $60.00 should the auto fail the emissions test. Costs for administering the program would be collected through the yearly inspection fee (less than $5.00). Though these data provide only a summary of much more detailed analyses, they do allow the decision maker to determine quickly the relative costs of such a program and where the responsibility for supporting the program would lie.

Key to the performance of a cost-benefit analysis of air quality control strategies is some perspective relative to the sufficiency of the analysis and an appreciation of the context in which it is to be placed. For example, the cost analysis of a control strategy may be relatively brief as the example shown for an inspection/maintenance program, if we can be assured that the most relevant research sources have been thoroughly investigated and if it is certain that no other relevant impacts have been overlooked. Similarly, while cost-benefit analyses will provide important information for decision making, it may not always be given the highest weight in selecting among alternatives. One may find, for example, that residents within a polluted city will consider their welfare or personal freedom in comparison to residents in other urban areas as it is affected by control strategies. This consideration is likely to be given greater weight than any cost-benefit computations, or predictions of future health problems that could result if strategies are not implemented. While there is no standard that will allow one to determine that the best job has been done in performing a cost-benefit analysis, the following discussion of other economic issues related to air quality control will hopefully provide some additional background and perspective to the analysis procedure described above.

Growth Issues

In dirty air regions, the potential for new industrial development may be limited by the strategies required to attain air quality standards. The EPA policy guide in such situations allows that new plants may locate or expand if emission reductions will be obtained from existing sources which would more than offset the additional pollution contributed by the new facility (see "Emission Offset Policy" in Appendix A for additional explanation of this policy).

TABLE 7

ECONOMIC IMPACT ASSESSMENT

Program:

Auto inspection and mandatory maintenance.

Operation:

Autos would be subject to yearly emission inspection requiring the cars to be tuned to factory specifications. Autos would be screened on the basis of a 40 percent rejection rate.

Consumer Costs:

Minimum cost: $5.00 for inspection sticker
Average minimum cost: $35.00 for small car tune-up
Average maximum cost: $65.00 for luxury car tune-up
Maximum cost: $600.00 - $1,000.00 for major engine overhaul

Cost Incidence:

The greatest economic burden for supporting the program would fall on low income car owners who would tend to have older and more difficult to maintain cars. Those owners who can just afford to maintain a car given present circumstances might be unable to assume additional maintenance required under program and, thereby, lose auto privilege.

Regional Impact:

Since local auto repair shops would implement program, monies spent to comply with the program would be retained and circulated regionally. Mandatory maintenance of autos could also act to stimulate auto repair sector, at least in the short run. In the long run, properly maintained autos may reduce major repair bills and extend the life of the car, thus reducing car repairs and new car sales.

Certified inspection stations would be required to purchase emission analyst equipment; mechanics may also require additional training to operate equipment and to make corrective repairs. These costs would be recovered through the inspection fees.

Regardless of this policy, one of the most important criteria for the evaluation of air quality strategies will be the effect such strategies will have on the development potential of the region. Consequently, the evaluation of planned industrial areas, railroad and highway expansion, and utility expansion policies will need to be carefully considered in order to construct a land use plan that will accommodate or mitigate the pollution impacts of new industries. Again, the regional comprehensive planning process is the key to the analysis of air quality impacts associated with industrial development. A positive approach of this kind can do much to avoid costly problems in future years by defining areas with poor dispersion characteristics, areas which will become "hot spots" if growth is not diverted to other areas, and industries which over the long run can produce additional pollution reductions that would allow for additional industrial development.

Geographic Incidence of Controls

Another important criterion for the evaluation of control options is the extent to which controls affect the economic potential or competitiveness of one area within the Region in relation to other areas. This issue will most likely be apparent in the consideration of control strategies that affect central business districts (CBD's). Since CBD's normally represent the areas of highest automobile and commercial density, they are areas where pollution abatement strategies may be most needed. Such controls, if they severely restrict mobility or the expansion potential of commercial areas, might hamper revitalization efforts in downtown areas or could place CBD's at a competitive disadvantage with outlying shopping districts that offer free parking, unrestricted access, etc.

On the other hand, an air quality control plan that provided strong incentives for the use of mass transit facilities might favor substantially the CBD area, since the central city district serves as the hub of the mass transit systems in most cities. Outlying areas, with poor transit access, may find that they cannot attract the customers or the employees they need to compete with the central city.

Additionally, the application of indirect source regulations which evaluate the design and scale of new commercial and business centers may be sufficiently restrictive so as to provide existing developments and CBD areas with an important competitive advantage over new centers.

Some attempt must be made, therefore, to balance the incidence of pollution strategies. The central business areas are an essential community focus for most cities, and efforts to maintain and revitalize these centers should be consistent with both economic and air quality goals. This may imply a greater emphasis on the highway element of the design, the incorporation of malls or other design features that increase both the attractiveness and air quality of central city areas, or greater attention to specialized transit facilities to reduce congestion within the CBD.

Income Group Incidence of Control Costs

Social issues, as we have seen in the previous section, are central to the evaluation of air quality plans. The analysis of economic costs and benefits among population groups within the region is one of the more direct ways of determining the social impact of air quality strategies. There are almost certainly population consequences of every control option and the selection of alternatives within each region should distribute cost burdens associated with controls as equitably as possible. For example, will future site areas for industrial expansion be more remote from population centers and, thus, require transit facilities to allow greater access of jobs to low income persons? What is the relation between areas of highest population density and predicted ambient concentrations; what efforts can be made to protect high density areas from the health and welfare costs of high pollution concentrations?

These are but examples of a wide range of situations that could be expected within each metropolitan area. The mapping of population characteristics is equally important as the mapping of pollution concentrations in the analysis process. Only through the systematic analysis of demographic and income characteristics of the area's population can a judgement be made of the population consequences of control strategies. In addition, areawide strategies must also be tested for cost equitability. Auto retrofit devices to control pollution for older cars, for example, could be expected to affect lower income groups disproportionately since they would be more likely to own older cars.

Fiscal Impacts of Air Quality Control

Because Federal automotive emission controls and new source performance standards will not necessarily provide for the attainment of air quality goals, local governments in most metropolitan areas will need to bear a portion of the cost of implementing air quality control plans. Locally applied programs may take the form of car-pooling programs, traffic improvements, power plant modification, mass transit improvements, and any of a large number of other alternatives. In analyzing the costs of various options, at least three criteria will need to be addressed.

The first criterion is the cost measure of each option in relation to other options that might achieve the same result. A car-pooling program, for example, may be a more cost-effective program for reducing automotive pollution than a highway program designed to improve traffic flows or an expanded bus system intended to increase transit ridership. While evaluation methods can only approximate the relation between dollars spent and pollution reduction, the summary of transportation models in Chapter III indicates how traffic volumes and traffic speeds are related to pollution levels, for example; and the engineering studies of transportation improvements relate construction programs and costs to changes in vehicular patterns. Similar estimates can also be made based on the expected ridership of commuters in car pools, or the increased ridership expected from expanded bus service.

The second evaluation measure would be the cost consequences on other capital improvement areas not directly related to the control strategy. Does a greater dispersion of industrial areas, for example, commit the city to a waste water collection system which would significantly affect the area's water quality management plan? Alternatively, will efforts directed towards achieving a nodal development pattern reduce not only traffic and air pollution, but reduce the utility costs of development as well? Such examples point out the importance of not only identifying the costs to other sectors other than air pollution control, but of identifying opportunities for cost savings. Savings in energy costs are closely related to reductions in air pollution and should be quantified as part of the analysis process in order to achieve wider support of control programs. Savings in the transportation and utility sectors might also be realized through a carefully developed program for air quality maintenance.

A third element in the fiscal analysis of control strategies will be the evaluation of inter-jurisdictional differences in the application of control programs. In general, one would hope that a control program would be applied at a regional or air basin level so that controls would not vary from jurisdiction to jurisdiction. In areas such as land use and zoning, however, local governments have maintained primary responsibility for regulation, and it can be expected that many options will relate in some manner to these areas. Failure to achieve a consistent set of programs may increase the cost of government in one area greater than in another that fails to adopt a comprehensive set of strategies. Such inequities imply not only a greater fiscal burden for the responsible community, but may reduce the competitiveness of one community in relation to another in attracting new businesses or additional residential growth. The ultimate result may be worsening of both local air pollution problems and fiscal capabilities.

Other Private Sector Costs

Not only are the development potential and development location of private industries related to air pollution control programs, but the actual costs of development may be affected by regional control programs. These costs may be reflected in more stringent design standards, through costly control devices, or through more lengthy testing and review procedures which can delay construction. Again, the analysis process must evaluate these factors and weigh the costs of control in relation to the benefits to be derived. Much can be done during this analysis phase to coordinate the requirements of air quality control with procedural requirements. Indirect source controls, for example, could be designed to parallel other review schedules for large developments and thus avoid the additional costs of delay. Other locally applied strategies such as transportation controls can be coordinated with developers' plans to create a better urban environment and a more saleable development than might otherwise be the case. In all cases a positive program is required which is geared to the anticipation of unusual cost impacts and the development of a control program which works to mitigate or reduce the impacts of control programs on the private sector.

Land Use Costs

One of the central arguments of this report is that land use strategies offer one of the most positive means of dealing with air pollution problems. By anticipating problems before land use decisions are made, more appropriate land use decisions can be formulated which largely avoid the economic consequences of air pollution control.

There are now a number of examples of systematic attempts to evaluate the economic and environmental costs of alternative development patterns. One of the most noteworthy of these attempts is represented by The Costs of Sprawl.[31] Its usefulness derives in part from the fact that a standard or typical building site is assumed and relationships with particular governmental jurisdictions are ignored. This allows the comparison of impacts from only one independent variable: the form of development. Consequently, the results and the methodology of the study can be generalized for a large number of other cases where the primary intent is to evaluate only the differences associated with development alternatives.

This report concludes that there are sizable savings in the utility costs associated with clustered and higher density developments. The data also demonstrate that there is less air pollution generated through more compact and better planned developments. The report also considers a number of other variables such as the energy costs associated with development, the costs to the private sector in building various kinds of housing patterns and the water quality impacts of various alternatives. Though parameters used to define impacts and costs will vary from region to region, the report does offer an excellent example of a methodology that is appropriate for evaluating the economic consequences of various land use alternatives constructed for air quality maintenance.

The Urban Land Institute has also sponsored detailed studies of the cost and environmental impacts of development.[32] Though the PUD study is not a comparative analysis, it does offer a methodology that allows the consideration of air pollution impacts of development along with cost considerations.

Conclusion

In areas where pollution problems are not overwhelming and where the political interest in pursuing yet another set of "bureaucratic" controls aimed at air pollution is also less than overwhelming, cost analyses will be a very important part of any effort to encourage a positive approach to air quality planning. As an initial effort, attention must be focused most heavily on those control strategies that offer cost advantages to businesses and individuals. Air quality strategies that are aimed at conserving the use of fuels, for example, offer a number of cost benefits in addition to the improvements expected in air quality. Car pooling represents another strategy which is relatively inexpensive to implement, particularly with funding assistance from DOT, and that offers savings for commuters in operating their automobiles. Other actions, such as those presented in the Transportation Systems Management Element of regional transportation plans, also offer opportunities to reduce the capital investment requirements for new transportation systems. Those actions that offer multiple advantages should be given greatest weight in the development of an air quality maintenance plan. An incremental approach which focuses at the outset on the most cost effective strategies for controlling air pollution will hopefully offer the greatest long run opportunity for constructing a comprehensive and publically acceptable set of air quality maintenance actions.

PLAN IMPLEMENTATION

The final element in the planning process outlined in Figure 1 is Plan Implementation. This element attempts to organize desired and appropriate land use and air quality strategies into some framework to give direct guidance on how to proceed.

The integration of air quality criteria in this case can best be structured in terms of the broader concept of urban systems management, or growth management. In the introduction to the three volume series of papers addressing the management and control of growth published by the Urban Land Institute, managed growth is defined as:

> "The utilization by government of a variety of traditional and evolving techniques, tools, plans, and activities to purposefully guide local patterns of land use, including the manner, location, and nature of development. Ideally, managed growth consists of a well-integrated, efficient, and affirmative system where choices or decisions are made explicitly and with full knowledge of the variables and trade-offs involved, and where the programs are coordinated in furtherance of clear community growth and land use objectives."[33]

Though the concept described above applies well to a comprehensive planning approach to air pollution, the impact of Air Quality Maintenance Plans on local planning, administration, and management will almost certainly mark a major departure from traditional forms of urban management. Though other programs have had a significant effect on the way environmental issues are treated, e.g., National Environmental Policy Act, Section "208" of the Federal Water Pollution Control Act Amendments, perhaps none is as far reaching in terms of its implications for urban growth and development as is the air quality planning process. In the large number of urban areas where changes in automotive and industrial technology will not be sufficient to achieve national air quality standards, basic changes in the form, intensity, and distribution of urban activities may be required. As we have noted, these changes will have significant social, economic, and political impacts. Technically there are a large number of alternatives for making cities more efficient and less polluted; however, these alternatives will undoubtedly change the way individuals behave or view themselves, and we can expect progress in improving the urban environment to be at times discouragingly slow, hotly disputed, and unnecessarily compromised.

From an urban management point of view, the implementation of air quality plans must not only deal fairly with this basic phenomenon of social change but it must organize and coordinate urban activities in a way that has been seldom achieved in this county. To a considerable degree, the problem of integration comes from the inability to find the institutional mechanism to establish efficient communication and to resolve issues. An attempt to organize air quality management within the existing framework of urban systems might be looked at as a Quixotic dream which can only serve to make our cities that much more unmanageable. On the other hand, such an effort might offer a refreshing and much needed new approach to urban management and provide the framework for the integration and coordination of environmental programs that has been sorely missing.

Obviously, management requirements will vary substantially depending on the kind of program elected to control air quality. An inspection/maintenance program for motor vehicles, for example, implies a much different kind of administration than the one that would be required for development reviews through indirect source regulations or a parking control plan as part of a Transportation Control Plan. This chapter will focus on the kinds of management alternatives appropriate for dealing with those control programs involving development, land use, transportation, and other comprehensive planning issues.

This approach recognizes the intimate relationship of air quality to the performance of other urban systems. These relationships have been described in Chapter I of this report; in summary, we can say that the operating policies of Federal agencies now require consistency of effort among air quality, water quality, housing, and transportation planning. It can also be expected that emerging policy areas such as energy will also explicitly require that consistency be achieved with air quality goals.

Despite these recently formulated requirements for plan integration, the history of urban systems management until these recent years has been more often centered on the formation of single purpose agencies. The tremendous problem of coordination and synchronization that has resulted from such a structure has long been recognized: each bureaucracy or organization attempts to achieve its own ends or accomplish its narrowly defined mandate, often regardless or in spite of other legitimate organizational objectives. An additional complication is that larger metropolitan areas not only have greater air pollution problems, but also have a larger number of management agencies. In the San Francisco area, for example, each of the following agencies play a significant role in defining development patterns and setting the environmental limits to such development:

ABAG	The Association of Bay Area Governments acts as the area-wide council of governments for comprehensive planning. Membership is strictly voluntary.

MTC	**The Metropolitan Transportation Commission is primarily responsible for transportation planning.**
BCDC	**The Bay Conservation and Development Commission is charged with preservation and regulation of development along the San Francisco Bay which touches several jurisdictions in the region.**
BAAPCD	**The Bay Area Air Pollution Control District is charged with the restoration and preservation of air quality.**
BASSA	**The Bay Area Sanitary Sewer Services Agency proves regional waste water systems.**
BAWQCB	**The Bay Area Water Quality Control Board is responsible for maintaining water quality standards.**
CALTRANS	**CALTRANS is the basic highway planning agency within the State structure for the Bay Area.**
BARTD	**The Bay Area Rapid Transit District provides communter rapid transit to the region.**

In addition to these agencies, there are two Coastal Commissions for preserving the coastline within the Bay Area, a number of other transit or transportation districts, and more than twenty cities and counties within the region. In addition to different systems assigned to each of these agencies, each has a different management function: planning, regulation, operations. Though each of these organizations is well intentioned, the time and effort needed to interact and coordinate is not programmed well enough to provide effective linkages.[34]

A 1974 report by the California Air Resources Board also found "a noticeable lack of coordination between air pollution control districts and local planning agencies". As of 1974, some local governments had never spoken to their local air pollution control districts.[35]

Organizational Requirements

The preceding discussion has pointed to one of the critical requirements of a structure for air quality management: it must be comprehensive in scope. Only in the smallest metropolitan areas could one expect an air quality control strategy involving only a single agency to be sufficient to attain and preserve air quality. Even if this were the case, there must be some mechanism for ensuring that the air pollution control strategy is consistent with other planning objectives, e.g., energy and transportation efficiency.

A second major requirement of the management system is that it have the regulatory and administrative powers to ensure compliance with the Air Quality Maintenance Plan and the State Implementation Plan. It must be able to achieve its goals without the crippling pressures of conflicting local interests. The managing organization must not only be able to promulgate regulations, but be able to offer both positive and negative sanctions to ensure compliance. Finally, the organization must be adequately funded to manage the plan and it must be professionally staffed. Each of these points, though apparently obvious, can have a crippling effect on an implementation program if omitted. Funding of the South Coast Air Quality Management District resulted only after a suit was filed by the State of California and the State's Air Resources Board and a subsequent decision by the California Supreme Court which ordered Los Angeles County to provide $2.3 million to the Management District in fiscal 1978. Voluntary agreements among agencies, though an important part of the planning process, will not be sufficient to ensure that air quality standards are achieved. This implies a more rigid structure defining responsibilities among agencies, and a more rigorous system to account for and control the air quality impacts of various urban systems.

A third requirement of air quality management is that it be prescriptive as well as prohibitive or regulatory in defining the program for achieving air quality standards. Such an approach not only assures that the decisions of the management organization will be predictable, but in fact establishes the rationale for making decisions. The prescriptive aspect of the program can take a number of forms, all of which may be important. The development of a comprehensive plan which establishes how land use, transportation, water systems, and other systems can best be organized to achieve air quality goals is a major component of a positive approach in decision making. The management organization may also be required to formulate development standards or performance criteria for effective control of individual land use decisions; such standards might be incorporated as part of indirect source regulations, for example. The management agency could also provide direction by developing a handbook of "best management practices" for controlling particulate problems, paralleling the water quality guidelines for controlling non-point sources of water pollution. Such examples are intended to reduce the number of "after the fact" judgments of whether or not development decisions are appropriate and to define more clearly the actions required by each of the actors in the overall program for air pollution control.

A fourth set of organizational requirements relate to public accessibility and accountability. While agencies must be free to override considerations of special interests that may in some way be adversely affected by regulation, they must also reflect the local consensus of how best to control air pollution problems. This raises a number of questions regarding the makeup of the governing membership of the management agency: whether they are to be appointed or elected, and who appoints or elects the membership. Regardless of the constitution, public accessibility must be a key organizational feature of the management program. One commonly employed procedure for ensuring that persons aggrieved by management decisions are treated fairly is to provide for administrative appeals. Such appeals are normally directed to a State or regional commission created to administer the law; failure to reach an agreement through this procedure would normally send the affected parties to the courts.

Such formal procedures, of course, need not be the only alternative pursued for increasing public involvement. Regular, open meetings within the metropolitan area can serve to keep the media and the citizenry aware of the status of programs. Seminars, public forums, television presentations, and other educational programs should also be developed as part of a continuous effort to elicit and maintain support for air quality programs.

In attempting to design for efficient management, the criteria outlined above should be of primary concern in evaluating organizational alternatives. It is most probable that no single alternative will offer all the features one would hope for in designing a management program. While one might also hope that a consistent management scheme be applied to most air quality programs, it is apparent that organizations and governments differ substantially among States. The selection of a management system within each air quality control region will depend on the nature of the air pollution problem, the suitability of local agencies for adaptation to new programs, the willingness of local governments to take responsibility for environmental management, and the support that can be expected from other key agencies.

The following outline of State, regional, and local organizations generally covers the range of alternatives that exist for air quality management. A number of sources have investigated the development of each of these alternatives for managing environmental problems.[36]

Vermont and Hawaii, for example, have developed strong State codes for controlling land use and environmental decision making. The Tahoe Regional Planning Agency, the Adirondack Park Agency, and the Twin Cities Metropolitan Council (Minneapolis-St. Paul) are examples of regional agencies that have been delegated special authority by the State to manage environmental systems. Boulder, Colorado, Ramapo, New York, and Petaluma, California have each developed strict local criteria for regulating and directing land use activities. None of these is without controversy; each, however, has demonstrated an innovative and aggressive approach to handling pressing environmental problems. The advantages and disadvantages of each of these approaches, along with a review of special purpose regulatory agencies, are summarized in the following outline.

REGIONAL RESOURCES AGENCY (SPECIAL PURPOSE REGULATORY BODIES)

Advantages

- A regional resources agency could be structured to handle major environmental systems, so as to consolidate the review and permit process and to reduce the number of bureaucratic agencies. Major candidates for such a program would be air quality, water quality, and energy. The Washington Environmental Coordination Procedures Act provides for such a joint review procedure in the State of Washington though regulatory agencies have not been consolidated.
- Such an organization could be combined with a regional service authority to guarantee that both public and private development decisions are coordinated with respect to environmental standards. Such an authority might include operating responsibilities for sewage systems, urban drainage control, solid waste management, regional parks and recreational facilities, and regional transportation facilities (airports, bus lines).
- A regional resources agency could be self sustaining through delegated taxing powers.
- The organization, if governed by local elected or appointed officials, would relate most directly to the lowest levels of of government.

Disadvantages

- Such an organization represents a new layer of government with regulatory powers independent from the operation of local governments.
- The political feasibility of the taxing plan is uncertain.
- Such a management plan runs the risk of delegating the authority for environmental issues to a single "czar".

STATE RESOURCES DEPARTMENT

Advantages

- States now bear the principal regulatory authority for air quality, water quality, and energy programs. A better coordinated or consolidated structure at the State level could thus provide a consistent and comprehensive approach throughout the air quality control regions.
- States have a broader tax base to draw upon to support environmental programs.

- States may often have a greater store of expertise that can be applied to resolve complex issues involving a number of local governments.

- States could regionalize their resources department, thus providing a greater measure of local participation.

- The consolidation of permitting procedures will require that all relevant facts and opinions be brought to bear on development proposals and will increase the certainly with which developers and private citizens can plan their affairs.

Disadvantages

- State authority may often overlap, authority may not be clear among various environmental programs, permit procedures often differ. To add rigorous air quality management requirements may only serve to complicate an already confusing array of State programs.

- States lack authority in development of zoning, subdivision, transportation, and other programs at the local level which may be critically important for developing an efficient air quality control program.

- Such an alternative would represent a greater State intervention in local affairs.

REGIONAL COUNCIL OF GOVERNMENTS

Advantages

- Councils of Governments represent to the greatest degree local interests through cooperative government.

- COGs have broad planning responsibilities in a number of environmental areas that mesh well with requirements for air quality maintenance planning.

- COGs may prepare long range transportation plans and be designated the Metropolitan Planning Organization for the allocation of Federal highway monies. Such an organization would be well suited for managing the transportation control plan required as part of the total air quality control program.

- COGs have review authority in the allocation of other Federal monies through the A-95 review process and could ensure that other development programs are consistent with air quality plans.

- Such a management plan would be consistent with Federal encouragement of regional agencies.

Disadvantages

- COGs typically have no regulatory or enforcement powers and are essentially advisory to local governments. Assignment of regulating powers by State would imply a major shift in COG functions and duties of elected officials.

- COGs have limited funding sources and must rely on voluntary contributions from local governments.

- COGs have no control over local zoning and subdivision, beyond their advisory capacity.

- The A-95 review process does not carry with it sufficient authority for effective or mandatory compliance with regional policies.

- An expanded role for COGs in air quality control would create an organization that might be competitive with both State and local governmental functions.

- COGs may often serve as the Metropolitan Planning Organization for transportation planning, and could be in the position of acting as its own judge with respect to evaluation of air quality impacts.

EXPANDED LOCAL AUTHORITIES

Advantages

- Locally constituted agencies are most sensitive to local conditions.

- Such organizations are more accessible to the citizenry and generally must demonstrate greater accountability to the public.

- Local administrative and enforcement agencies are already in place.

- An organization mandated by local elected officials would have more direct, and therefore, more efficient control over operating agencies such as public works, utility department, transit system, zoning and subdivision review.

Disadvantages

- Local government has limited power to control extraterritorial impact of pollution.

- Local governments are often dependent on continued growth and could not effectively exercise discretion in handling of environmental issues.

- Local governments would be in a position of ruling on the adequacy of its own operation of facilities.

- Local expertise is often absent, particularly in small communities, for handling complex environmental problems.

Conclusion

Implementation of any of the management alternatives described here would disturb the inertia of numerous State and local decision making processes. However, the proliferation of environmental and land use controls at all levels of government has greatly increased the complexity of the development process. At some point, the need for greater efficiency and for simplification of the regulatory and management structure must outweigh the relative ease with which a new, simple purpose regulatory agency can be constructed. This observation would seem appropriate to the consideration of air quality management alternatives, and it is concluded that such an approach will offer the most effective and most efficient framework for air quality plan implementation.

CONCLUSION

For those regions that are approaching or have exceeded national ambient air quality standards, the systematic consideration of air quality criteria in the comprehensive planning process is a prerequisite to the development of effective air quality control strategies. This process does not imply, however, a massive, single purposed effort on the part of regional planning agencies. It is rather a logical extension and derivative of those analyses normally required to assess other region-wide problems such as transportation systems and water quality. Particularly for those areas undertaking a detailed study of water quality management issues with Federal assistance through the "208" program, the opportunities that exist for coordination and parallel planning activities simplify greatly the demands of constructing a comprehensive air quality planning program. This coordinated planning process allows for greater administrative efficiency through parallel planning and review procedures, it allows for the more immediate resolution of problem areas through parallel analysis and impact assessment, and it will allow for greater system efficiency through the design and implementation of strategies directed to multiple planning objectives.

The basic framework for this process is provided through the land use planning and forecasting tools. Land use models serve to organize and simplify the policy and information requirements for constructing future land use projections. They also allow the analyst to construct a number of land use, population, and employment distributions or growth scenarios; this allows the comparison and evaluation of a number of growth alternatives and allows the selection of most appropriate land use policies for satisfying regional goals and objectives. These goals and objectives are typically stated in the form of more specific development criteria and include social, economic, and environmental measures which can be used to provide a quantitative and qualitative evaluation of growth alternatives.

Air quality criteria are provided through national and state standards for air quality. The regional evaluation of air quality impacts is constructed using a set of air quality models which forecast ambient pollution concentrations based on the region's meteorology and the expected levels of urban activities. Urban activities are associated with the generation of air pollutants through a series of emission factors which are compiled in the emission inventory. The air pollution models replicate the diffusion and dispersion of these emissions on a regional scale and can be used to locate future problem areas and to evaluate the impact that alternative land use configurations can have on the reduction of pollution problems.

In general, one would find that there are limits to the pollution reductions that can be achieved through land use strategies. This is related, in large part, to the fact that the form of metropolitan areas have largely been determined by transportation networks, the location of major employment centers, and the installation of other major infrastructure elements. These systems are relatively inelastic and serve to constrain the alternatives that exist for future development. Regions that are experiencing air pollution problems, therefore, will characteristically need to consider more specific air quality control strategies in order to control the sources of air pollution. These strategies, because they affect the transportation sector, the uses of energy, or elements of technology related to industry, are also intimately tied to the performance of urban systems. These system relationships can also be evaluated using qualitative and quantitative tools outlined in this report. Two of the more complex analysis areas--social and economic analyses--have been considered in greater detail in order to demonstrate an appropriate methodology for evaluating these impacts.

Finally, this report has outlined the salient issues in the implementation of an air quality maintenance program and has argued that effective air quality control will depend to a substantial degree on the efficiency and comprehensive nature of the management program.

These considerations, if conscientiously applied, can provide for the successful integration of air quality in a comprehensive planning process. Inevitably, there will be cases where a region cannot hope to optimize all of the standards or criteria which it must consider in making decisions. In systems analysis terms, the integration process outlined here is a process of "global-optimization" in which trade-offs must be considered in order to achieve some balance among financial, social, and environmental constraints. Regional plan management must provide a land use system that is fiscally efficient, workable, and rewarding for the private sector. At the same time, it must be environmentally sound and work for the maintenance of a quality of life we all cherish.

However, the framework outlined here cannot be achieved by a "business as usual" attitude. It will require foresight and dedication on the part of decision makers, and flexibility and innovation on the part of planners. Though it may seem unreasonable to make decisions now that will be best appreciated twenty-five years from now, rapidly changing technology, energy balances, income distributions, and a host of other factors require that proper decisions be made now if we hope to maintain the quality of life and character of cities that we all deserve.

APPENDIX A

GLOSSARY OF AIR POLLUTION TERMS

Adiabatic	Occuring without gain or loss of heat. In a dry atmosphere, the adiabatic lapse rate (rate of temperature decrease with increase in elevation)is one degree Centigrade per 100 meters. When the actual lapse rate is greater than this theoretical rate, a parcel of air that begins to rise continues to do so, and the atmospheric condition is called "unstable". If, however, the actual lapse rate is less than the adiabatic rate, the surface air remains near the surface and the atmospheric condition is called "stable".
Aerosol	A dispersion of solid or liquid particles of microscopic size in a gaseous media. Examples are fog, smoke, and mist.
Air Quality Control Regions	Pursuant to provisions of the Clean Air Act amendments, States were required to identify areas that currently exceed any of the national air quality standards or that may have the potential for violating standards based on projected growth in the area. In almost all cases, Air Quality Control Regions correspond to County boundaries or groups of Counties.
Air Quality Maintenance Plan	The Natural Resources Defense Council and various other petitioners challenged the EPA Administrator's approval of State Impelentation Plan on several grounds, including the contention that the plans approved were not adequate to ensure maintenance of the National Ambient Air Quality Standards once they were attained. The Court ruled in NRDC v.EPA (475F. 2d 968, D.C. Cir. 1973) that State Implementation Plans were in fact inadequate and ordered the administrator to review SIP provisions for maintenance of air quality. The administrator determined that no SIP had adequately analyzed the impact of growth. Air Quality Maintenance Plans are intended as revisions to the SIP specifying how standards can be maintained over the next ten years.

Ambient Air	Ambient air refers to free, atmospheric air. The term "ambient" is to distinguish this class of controls from those that may apply to industrial plants, public smoking, etc.
APRAC	APRAC is a regional dispersion model for line sources which can be used to predict one hour or eight hour concentrations of CO at specified receptors near major traffic segments.
Carbon Monoxide	(CO) Carbon monoxide is formed from the incomplete combustion of carbonaceous fuels; the automobile is the primary source of this gas in an urban environment. Carbon monoxide is a poisonous gas which has a strong affinity for hemoglobin, reducing the bloodstream's capacity to carry oxygen.
CDM	Climatological Dispersion Model. CDM is a Gaussian plume model using frequency distributions of annual meteorological conditions. It predicts annual arithmetic mean concentrations at any number of receptor sites.
Cold Start	A cold start occurs when an automobile engine is started after a period of non-use. When an engine is cold, the carburetor does not effectively vaporize the gasoline before it is injected into the combustion cylinders. A phenomenon of "Quenching" also occurs which relates to the cooling of the combustion flame as it contacts the cylinder wall; this further reduces the combustion efficiency. These factors lead to greatly increased exhaust emissions, especially hydrocarbons during the warm-up period.
Diffusion	Mixing of pollutants with surrounding air by means of random particle or molecular motion.
Dispersion	Transport of pollutants by atmospheric currents. (Often used interchangeably with diffusion).
Emission Charges	Fees or taxes proportional to the emission rate of a given air contaminant may be levied to offset the public cost of air pollution sources. Special taxes, for example, reduced real estate taxes while land is used for low intensity purposes, or other fiscal incentives have also been suggested as measures that can be designed to maintain clean air standards.

Emission Density Zoning

(also dubbed "unit area emission quotas") This regulatory measure assigns specific, maximum allowable area emission rates to different classes of land use. This measure represents the air pollution control analog of traditional building density limits. For example, a emission density zone might establish an upper limit of three tons per year of hydrocarbon emissions per acre of land in areas zoned for heavy industry; an industry with controlled emissions of 1.5 tons of hydrocarbons per year would require a site of at least one/half acre designated "heavy industry". Emission density zoning also offers a regulatory and administrative framework compatible with the concept of transferable emission rights. Using the previous example, such a plan would allow an owner of two acres of land in an area designated "heavy industry" to sell or otherwise transfer emission rights equivalent to six tons of hydrocarbons per year to owners of adjacent properties.

Emission "Offset" Policy

In areas that currently exceed national ambient standards, the 1977 Clean Air Act Amendments make law a policy for the location of major stationary sources (Section 173). The most controversial feature centers around whether or not the regulation is in effect a "no growth" control of dirty air regions.

Section 173 specifies that if a proposed source would exacerbate an existing violation of ambient air quality standards, then they are subject to a preconstruction review. Construction approval may only be granted if the following conditions are met:

1. The new source is required to meet an emission limitation which specifies the lowest achievable emission rate. In no event could the specified rate exceed existing emission standards for new sources.
2. The new source (and other sources controlled by the applicant) must be in compliance with all SIP requirements or in compliance with an approved schedule and timetable for meeting SIP provisions or enforcement orders.
3. Emission reductions ("offsets") from existing sources in the area of the proposed source are required to provide a reduction in total emissions allowable under the SIP, in order to represent reasonable progress attainment of national ambient standards.

Episode	The occurrence of stagnant air masses during which air pollutants accumulate, so that the population is exposed to an elevated concentration of airborne contaminants.
Federal Motor Vehicle Control Program	The Clean Air Act Amendments of 1970 mandated progressively more stringent emission standards in light duty motor vehicles for hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NO_x). These percentages were translated by the 1977 Clean Air Act Amendments into the following numerical standards: HC 0.4grams/mile CO 3.4grams/mile NO_x 1.0grams/mile The 90% requirements have been suspended a number of times by EPA and Congress. Interim standards have achieved an 82% reductions in these pollutants.
Fugitive Dust	Fugitive dust includes solid particules released into the atmosphere by natural forces or by mechanical processes such as crushing, grinding, milling, demolishing, or sweeping.
Hot Soak	The hot soak occurs at the end of an automotive trip after the engine is shut off. When the engine is turned off, the gasoline remaining in the carburetor or the connecting system that would have been burned had the engine continued running is instead vaporized by the engine heat and escapes to the atmosphere.
HIWAY	The HIWAY model estimates one hour CO concentrations at any receptor location downwind of a highway segment (line source). The HIWAY model is often used in project level analysis (a new roadway, bridge, etc.) because of its simulation of a small area with detailed input data.
Hydrocarbons	(HC) A number of hydrocarbon compounds are emitted from automobile exhausts and crankcase emissions. The olefins, one important series of hydrocarbons, participate in a complex set of reactions in the presence of nitrogen dioxide and sunlight to produce ozone, aldehydes, and a variety of other organic compounds that contribute to smog.
Indirect Sources	(variously called complex sources) Indirect sources represent those facilities that do not themselves produce pollutants but which generate or attract vehicular activities resulting in air contamination. Indirect sources may include parking lots, highways, shopping centers, and apartment complexes.

Indirect Source Review	States may elect as part of the State Implementation Plan to include regulations which would mandate reviews of the planning, siting, and design of auto related facilities. This preconstruction review would evaluate the air quality impacts of the major developments and could cause them to be redesigned or relocated if they would result in new air quality standard violations or worsened existing violations. Although the EPA has suspended application of the national regulations on indirect sources, States have now implemented their own regulations controlling indirect sources of air pollution.
Inversion	A layer of air in which temperature increases with height. Because colder, heavier air is trapped near ground level, inversion conditions are associated with increases in air pollution and episode conditions.
Line Sources	Line sources of air pollution include streets and highways which generate air pollutants as a result of vehicular traffic.
Modal Split	The calculation of the proportion of total person trips which will use available transportation modes.
Mode	Method of transportation, such as bus, auto, walking, rapid transit, taxi, or bicycle.
National Ambient Air Quality Standards	Under Section 109 of the Clean Air Act of 1970, the Administrator of the EPA was required to set two sets of standards; primary and secondary. Primary standards are ambient standards based on criteria documents and allowing an adequate margin of safety adequate to protect human health. Secondary standards are standards which are adequate to protect the public welfare (visibility, quality of life, property, plant life, and similar values). Pursuant to the Act, the Administrator of the EPA has established standards for six major pollutants or classes of pollutants: hydrocarbons, sulphur oxides, photochemical oxidants, carbon monoxide, oxides of nitrogen, and particulates.
Nitrogen Oxides	(NO_x) There are six known oxides of nitrogen, two of which are considered as air pollutants. Nitric oxide, the primary product, is associated principally with the internal combustion engine and is formed when combustion takes place at a sufficiently high temperature to cause reaction between the nitrogen and oxygen of the air. Nitric oxide may be coverted to nitrogen dioxide through photochemical or other processes; nitrogen dioxide is considerably more toxic and is the only widespread pollutant gas that is colored.

Particulates	Particulates are finely divided particles of matter or dust that occur from unpaved roads, bare or stripped ground areas, industrial processes, and in other ways. Apart from visual and aesthetic effects, particulates can be a serious pollutant because of respiratory effects.
Para Transit	Para transit refers to a class of vehicles apart from conventional bus transit. It is usually distinguished from transit either by smaller vehicles or the provision of demand responsive services. Examples are mini-buses, multiple occupancy taxies, jitneys (small vehicles on fixed street routes), van pools, and subscription buses.
Photochemical Oxidants	Photochemical oxidants are a series of compounds which are formed in the presence of sunlight and other air contaminants, primarily auto emissions. Ozone is one of the most toxic of these compounds and is responsible for more injury to vegetation than any other air pollutant. In some species, damage can occur at ozone concentrations of a few parts per hundred million; such concentrations have been observed more than 70 miles from large metropolitan sources.
PLUM	Projective Land Use Model. PLUM is a computer model designed to simulate development patterns in an urban region. The function of PLUM is to distribute a specific amount of future growth to zones within the region given specific sets of growth policies, development constraints, the existing distribution of activities, and other information. Data generated through PLUM form the basis for the area source inventory component of the air quality model system.
Plume	A column of smoke.
Prevention of Significant Deterioration	Final EPA rules for the prevention of significant deterioration of air quality were promulgated on November 27, 1974, with the effective date of the regulation January 6, 1975. EPA's specific regulations were upheld by the D.C. Court of Appeals in 1976. Nevertheless, the non-significant deterioration provisions continue to be a controversial area within the clean air program, and this concept has been restated and reaffirmed in the 1977 Clean Air Act Amendments.

As presently constituted, regulations for the prevention of significant deterioration apply only to sulfur dioxide and suspended particulate matter. Section 166 of the Clean Air Act Amendments calls for the EPA to promulgate regulations by August, 1979 to prevent the significant deterioration of pollutant levels of hydrocarbons, carbon monoxide, photochemical oxidants, and nitrogen oxides. All land areas with air quality better than national standards are subject to an area classification procedure. There are three classes of areas, each with a different allowance for increases in ambient air pollution concentrations. A Class I designation applies to areas where almost any deterioration of current air quality would be considered significant (wilderness areas, national parks, etc.). Class II applies to areas in which deterioration normally accompanying moderate growth would be allowable. A Class III designation would apply to areas where substantial energy or industrial development is expected and where increases in ambient concentrations up to national standards would be allowed. States are primarily responsible for determining area classifications.

Primary Standards	National primary standards for air quality define levels of air quality which the Administrator of the Environmental Protection Agency judges are necessary to protect public health.
Rollback	Rollback is a "desk top" model that allows the estimation of future pollution concentrations (at the worst site in the region) given a set of emission inventories for the future year investigated. Rollback assumes that changes in air pollution concentrations in a region are proportional to changes in emissions.
Secondary Standards	National secondary standards for air quality define levels of air quality judged necessary to protect the public welfare from the adverse effects of air pollution.

Section 109j	Section 109j, Title 23, USC (added Section 136b of the Federal Aid Highway Act of 1970, P.L. 91-605) states, "The Secretary, after consultation with the Administrator of the EPA shall develop and promulgate guidelines to assure that highways constructed pursuant to this title are consistent with an approved plan for the implementation of any ambient air quality standard for any air quality control region designated pursuant to the Clean Air Act, as amended." The Senate Public Works Committee produced the 1970 amendments to Clean Air Act and the 1970 Federal Aid Highway Act. Section 109j was added to ensure consistency between the two acts. The guidelines that have been developed to implement Section 109j require an annual review of Federal assisted highways to ensure their consistency with the SIP.
Spider Network	A network based on straight-line connections between centroids of urban districts or zones. Spider networks are sometimes used in preference to networks simulating roadway or transit systems in order to reduce computer running time and to simplify data inputs to the modeling process.
State Implementation Plan (SIP)	Section 110 of the 1970 Amendments to the Clean Air Act required each State to formulate a plan that will provide for the attainment, maintenance, and enforcement of the National Ambient Air Quality Standards for each of the Air Quality Control Regions within the State. The Act required the plan to specify strategies for meeting both primary and secondary standards in each of the control regions.
Stationary Sources	(also called point sources or direct air contamination sources) Stationary sources of pollutants are facilities that are fixed in place and which release pollutants as part of the operation of the facility. These would include power plants, cement batching plants, and other kinds of industrial operations. EPA defines point sources as any stationary facility which has the potential of emitting 100 tons per year or more of any one pollutant for which there is a national standard.

Sulfur Dioxide	Sulfur dioxide is the most common of the sulfur oxides that occur as pollutants in the atmosphere. This is a product of combustion of fossil fuels containing sulfur, primarily coal and fuel oil. Sulfur dioxide combines with water in the atmosphere or a respiratory tract to form sulfurous and sulfuric acids. These acids attack materials, plants, and lung tissues.
Traffic Assignment	A modeling process to predict the number of trips traversing specific roadway or transit route segments. Trips from all origins to all destinations are assigned to specific routes, based on travel time or travel costs.
Transportation Control Plan (TCP)	A transportation control plan is a plan that describes the transportation control measures that will be required in order to achieve and maintain ambient air quality standards.
TSP	Total Suspended Particulates.
$\mu g/m^3$	Micro grams per cubic meter. A micro gram is one millionth of a gram.
VMT	Vehicle Miles Traveled.

TABLE 8

FEDERAL AND STATE AIR POLLUTION STANDARDS

POLLUTANT	AVERAGING TIME	EPA PRIMARY		EPA SECONDARY		COLO. 1973		COLO. 1976		COLO. 1980	
		(At typical conditions)***				(At typical conditions)***					
		$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm
CARBON MONOXIDE	1 Hr.	40,000	35	40,000	35						
	8 Hr.	10,000	9	10,000	9						
HYDROCARBONS	3 Hr. (6 to 9 a.m.)	160	0.24	160	0.24						
NITROGEN OXIDES											
(ARITH. MEAN)	Year	100	0.05	100	0.05						
PARTICULATES	24 Hr.	260		150		200		180		150	
(ARITH. MEAN)	Year					70		55		45	
(GEOM. MEAN)	Year	75		60							
PHOTOCHEMICAL OXIDANTS	1 Hr.	160	0.08								
SULFUR DIOXIDE	1 Hr.**					800	0.28	300	0.10		
	3 Hr.	1300	0.5	1300	0.5						
	24 Hr.	365	0.14			300	0.10	150	0.050	55	0.020
(ARITH. MEAN)	Year	80	0.03			60	0.020	25	0.0090	10	0.0040

*Maximum permitted once per year for indicated averaging time.

**Maximum permitted once per month.

***To convert values in ppm to $\mu g/m^3$, multiply ppm x ρ, where $\rho = \frac{mp}{RT}$, m is the molecular weight of the pollutant in g/m, p is pressure in millibars, R is the gas constant (0.0831436 mb - m^3/mol - ^oK), and T is temperature in ^oK. For example, at a temperature of 50° F. (283.15° K) in Colorado Springs, $\rho_{CO} = 935.0$ and $\rho_{SO_2} = 2137.1$. At sea level at 50° F., $\rho_{CO} = 1246.7$, $\rho_{SO_2} = 2754.6$.

APPENDIX B POLLUTION INDEX [37]

For long range planning it was desired to develop indices for each PLUM zone that describe the air pollution in each zone and the cumulative effect on the population of each zone of concentrations of all the pollutants. Both indices would relate the concentrations to standard values.

The numerical range of the index was to be broad enough to encompass and distinguish various possible situations yet small enough to give the user a tool that summarized, rather than detailed, the importance to air quality of alternative land use plans, zoning decisions, or judgements on individual projects.

Basic Description of the Index

To qualify the relative importance to health and welfare of predicted concentrations of each atmospheric pollutant, the concentrations were weighted inversely by their standards. These standards were determined after evaluation of the health and welfare effects that were summarized in the criteria documents of the EPA. The index is described by writing a term for each receptor as:

$$I_{ij} = (C_{ij}/S_i)$$

and is then summed over all pollutants to give:

$$I_j = \sum_i (C_{ij}/S_i)$$

where i refers to each pollutant and j refers to each receptor point in a PLUM zone, C is the predicted concentration, and S_i is the ambient annual average standard given in Table 8. This equation is similar to that used in the Oak Ridge work.

TABLE 9
AMBIENT ANNUAL AVERAGE STANDARDS

Pollutant	Standard ($\mu g/m^3$)	Backgrounds ($\mu g/m^3$)
CO	3240	93.5
HC	28.3	-*
NO_2	100	1.54
SO_2	60	0.427
Particulate Matter	44.4	29

*No appropriate factor for hydrocarbons was found.

This term was scaled to have convenient numerical values of lower and upper limits by writing it as:

$$I_j = a \sum_i (C_{ij}/S_i)^n$$

where a and n are constants determined by setting the C_i first equal to background concentrations given in Table 8 and then equal to their standards, and letting I = 10 and 100 for each case. It is assumed here that the background concentration of each pollutant is constant over the Region of interest; thus the B_i are independent of j.

The result is an index I_j at each receptor which has a value 10 when there is no locally generated air pollution, and a value 100 when local concentrations are all at standards, or when a situation considered equivalent to having all concentrations at standards exists. We determined the values a = 15.911 and n = 1.326.

Probability of Receptor in PLUM Zone

Each PLUM zone has analytically, an arbitrary size and shape; therefore, the receptor points at which concentrations are calculated are distributed non-uniformly with respect to the PLUM zones. Some receptor points that influence a zone may even lie outside the zone.

A zone is affected by concentrations at receptor points in and near it. Ideally the relationship of each receptor to zone boundaries should be determined, but this cannot easily be done in a computer program because of the arbitrary boundaries of each zone. Instead, the program determines the probability of a receptor affecting a zone.

It is assumed that those receptors out to a distance 2R from the centroid of the zone will determine the zone's air quality, where $R = A/\pi$ and A is the area of the zone. The probability that a receptor will affect the zone is given by:

$$P(j) = Be^{-r_j^2/R^2}$$

with the condition that $\sum_j P(j) = 1$ so that:

$$B = 1/\sum e^{-r_j^2/R^2}$$

where r_j is the distance from the centroid to the receptor.

PLUM Zone Air Pollution Index

The air pollution index for a PLUM zone is formed by weighting the index at each receptor by the probability of its effect on the zone and summing over all receptors in the circle of radius 2R about the centroid. This is written as:

$$I_p = \sum_j I_j P(j)$$

or

$$I_p = \frac{\sum_j e^{-r_j^2/R^2} \, a\sum_i (C_{ij}/S_i)^n}{\sum_j e^{-r_j^2/R^2}}$$

PLUM Zone Air Pollution Population Index

In addition to knowing the index of air pollution in a zone it is desirable to have a distribution of how people in a zone are affected by the air quality within the zone. This requires additional assumptions, which increase the uncertainty in the output, especially for small zones.

First, a value for the average population within the zone is obtained. This value is a function of the number of residents and the amount of employment within the zone and is approximated by:

P_N = $(E_N + (P_N \times (3. - \text{ERATIO})))/3$

P_N = average population in zone N of X zones

E_N = employment in zone N

P_N = total employment in the Pikes Peak Region/total population in the Region

Once the average population is obtained, the distribution is formed by reverting to the concept that each receptor influences a different number of people in a PLUM zone in relation to its distance from the centroid of the zone. Then, by using the probability function given in Eq. (4), the number of people exposed at least to the air pollution index at receptor j is $P_N(j)$.

APPENDIX C THE COLORADO SPRINGS EXAMPLE

This report alludes to the Colorado Springs metropolitan area in a number of instances, and the planning process described in the report was drawn to a substantial degree from the planning experience within the Pikes Peak Region. Part of the rationale in using the Pikes Peak Region as a model relates to the fact that it is a medium sized metropolitan area and therefore has data and information needs that require the use of specialized planning and modeling tools. At the same time, the area is not so large that its information system or its air pollution problems are overwhelmingly difficult to address. In addition, the region is relatively uncomplicated in organizational terms, since the Council of Governments serves as the designated "208" water quality management agency, it serves as the Metropolitan Planning Organization for transportation planning purposes, it reviews all Federal funding applications to the region through the A-95 process, and it is the lead agency in the air quality planning process. Program integration, therefore, is largely a matter of intraoffice coordination. For these reasons, the Pikes Peak Region serves as a rather straightforward example for planning purposes, and it can also be considered to be representative of a wide range of other metropolitan areas with similiar planning needs and resources. In order to better reference the Pikes Peak Region in relation to other regions, the following planning summary is provided.

El Paso County is the designated Air Quality Maintenance Area in the Pikes Peak Region. El Paso County has an estimated current population of 309,000 persons and an area of 2,150 square miles. Virtually the entire eastern half on the county is a sparsely populated high plains area whose principal land use is grazing. Some irrigated and dry land farming also occurs, both somewhat uncertain industries -- the former because of uncertain aquifer recharge and the latter because of very poor soil and moisture conditions.

The principal air pollution problem is located in the metropolitan area of the County, Colorado Springs being the principal focus of the urban area. Colorado Springs is a low density city with a current estimated population of 191,600 in an area of 57,549 acres (90 square miles); in 1974, 46% of the land area in the City was vacant. Growth is expected to increase at a moderate rate within roughly the same geographic area with an expected population of 417,320 in the year 2000. El Paso County is expected to reach a population of 554,600 in the year 2000, including Colorado Springs; most of the additional population will be located in urban areas adjacent to Colorado Springs.

TABLE 10

Population and Size Comparisons
United States Cities

City	Size in Square Miles	1973 Est. Population
Baltimore, Maryland	78.3	878,000
Brooklyn, New York	70.3	2,485,000
Cincinnati, Ohio	78.1	426,000
Colorado Springs	89.9	191,600 (1977 Est.)
Milwaukee, Wisconsin	95.0	691,000
Portland, Oregon	89.1	378,000
Sacramento, California	93.8	267,000
Seattle, Washington	83.6	503,000
Toledo, Ohio	81.2	377,000
Tucson, Arizona	80.0	308,000
Washington, D. C.	61.4	734,000

Air Pollution Summary

The EPA Regional Administrator has called for State Implementation Plan (SIP) revisions for two pollutants in the El Paso County Air Quality Maintenance Area: particulates and carbon monoxide. There are virtually no large, polluting industries in the Colorado Springs Area. Government represents the largest employer, most of this accounted for by military installations in the region -- NORAD, Fort Carson, the Air Force Academy, and Peterson Air Force Base. Light manufacturing represents the next largest basic employment sector, including several electronics industries -- Hewlett Packard, Ampex, Honeywell, and Digital Equipment. Tourism in the region accounts for approximately 10% of total retail trade and continues to be an important local industry.

Carbon monoxide pollution is, thus, largely attributable to auto pollution. In 1980, roughly 94% of the total carbon monoxide emissions will still derive from vehicular use in the region. Violations of the national eight hour standard for carbon monoxide are predicted to occur at a number of sites in 1980. (38) Most of these sites fall along the axis represented by the major transportation corridor (I-25) and the central city area of Colorado Springs. The area adjoining the intersection of two major arterials in the eastern sector of the City (Academy Boulevard and Platte Avenue) is also projected to account for multiple violations of the eight hour standard in 1980.

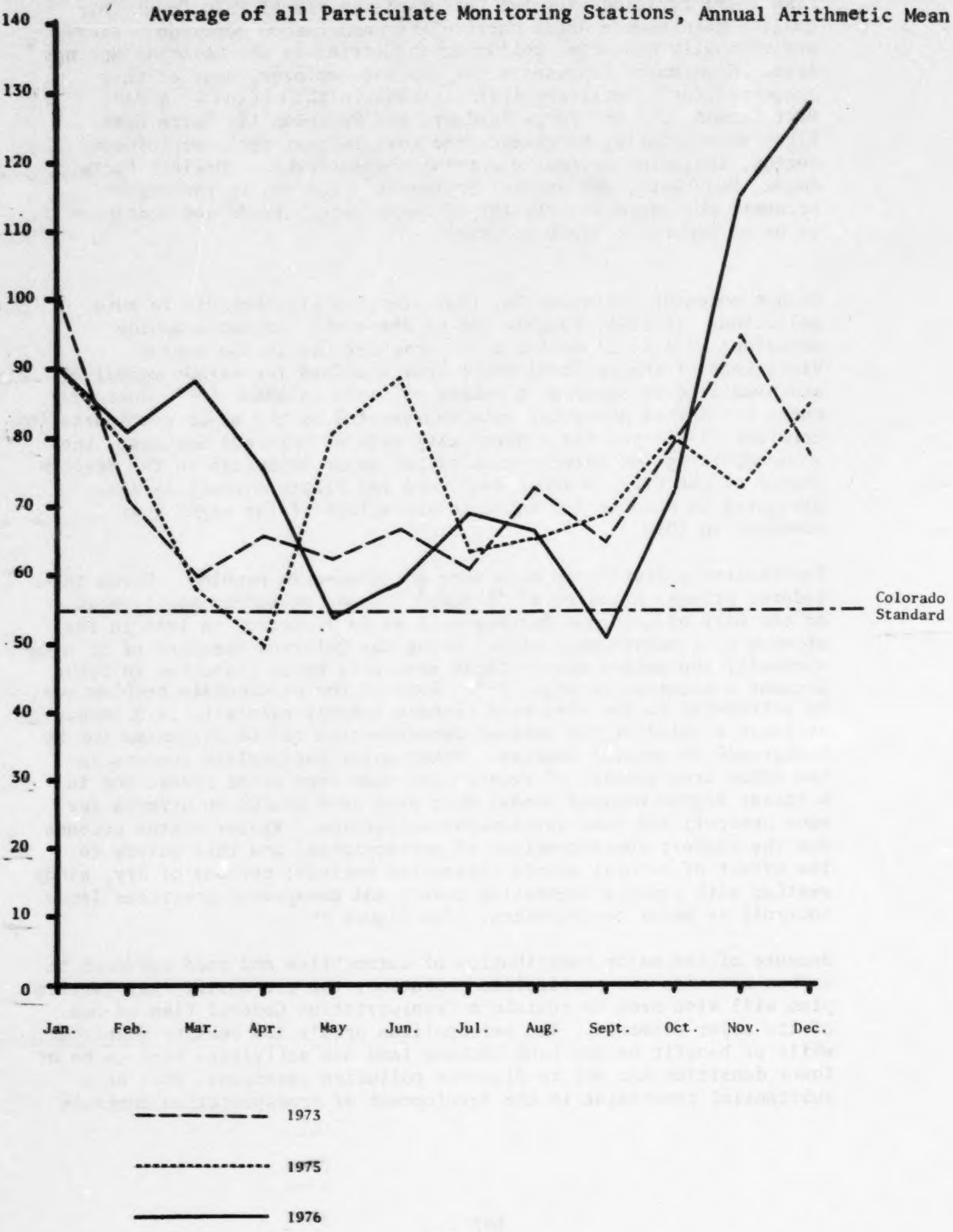
Particulate pollution is much more a region-wide problem. Using the Federal primary standard of 75 ug/m^3 (annual geometric mean), most of the City of Colorado Springs will be in violation in 1985 in the absence of a maintenance plan. Using the Colorado standard of 55 ug/m^3, virtually the entire metropolitan area will be in violation in 1985. without a maintenance plan. (39) Part of the particulate problem can be attributed to the semi arid climate (annual rainfall, 14.5 inches); at least a third of the ambient concentration can be accounted for by background or natural sources. Other major particulate sources in the urban area consist of reentrained dust from paved roads, and to a lesser degree unpaved roads; dust from sand placed on streets for snow control; and land development activities. Winter months account for the highest concentrations of particulates, and this points to the effect of natural events (inversion periods; periods of dry, windy weather with reduced vegetative cover) and management practices (snow control) as major contributors. (See Figure 7)

Because of the major contribution of automobiles and road surfaces to carbon monoxide and particulate pollution, the air quality maintenance plan will also need to contain a Transportation Control Plan as one of its major elements. The metropolitan area's low density character, while of benefit on one hand because land use activities tend to be of lower densities and act to disperse pollution emissions, will be a substantial constraint in the development of transportation controls

FIGURE 7

SUSPENDED PARTICLES
Concentration (Micrograms/M^3)

Average of all Particulate Monitoring Stations, Annual Arithmetic Mean



since the area is almost wholely dependent on the automobile. Similiarly, the region's existing transportation and infrastructure systems define to a substantial degree the future alternatives that exist for transportation plans, and major shifts in vehicular patterns and emission patterns can not be expected.

Land Use Scenarios

In order to better identify the air quality impact of alternative land use patterns, five growth scenarios were constructed and analyzed as part of the "208" water quality planning program. These scenarios were used to investigate the costs and benefits associated with other urban services and facilities as well; principal among these, of course, was waste water treatment systems. The growth scenarios are summarized as follows:

OPTION 1 - Satellite Cities in Woodland Park and Fountain, Infilling in all other municipalities. Under moderate growth.

- 550,000 people in the area by the year 2000
- 210,000 employees in the area by the year 2000
- Minimum annexation in all communities except Woodland Park and Fountain
- Increased developmental densities
- No expansion of utility service areas except in Woodland Park and Fountain.

OPTION 2 - Infilling and Slow Growth

- 365,000 people in the area by the year 2000
- 150,000 employees in the area by the year 2000
- 150,000 employees in the area by the year 2000
- Reduced annexation in all communities
- No expansion of utility service areas
- Application of growth controls required.

OPTION 3 - Satellite Cities under Moderate Growth

- 550,000 people in the area by the year 2000
- 210,000 employees in the area by the year 2000
- Expanded utility service area on a controlled basis in Woodland Park, Fountain and in New Town area
- New Town of 60,000 a possibility
- Open Space links required to guide growth and development.

OPTION 4 - Current Trends and Moderate Growth

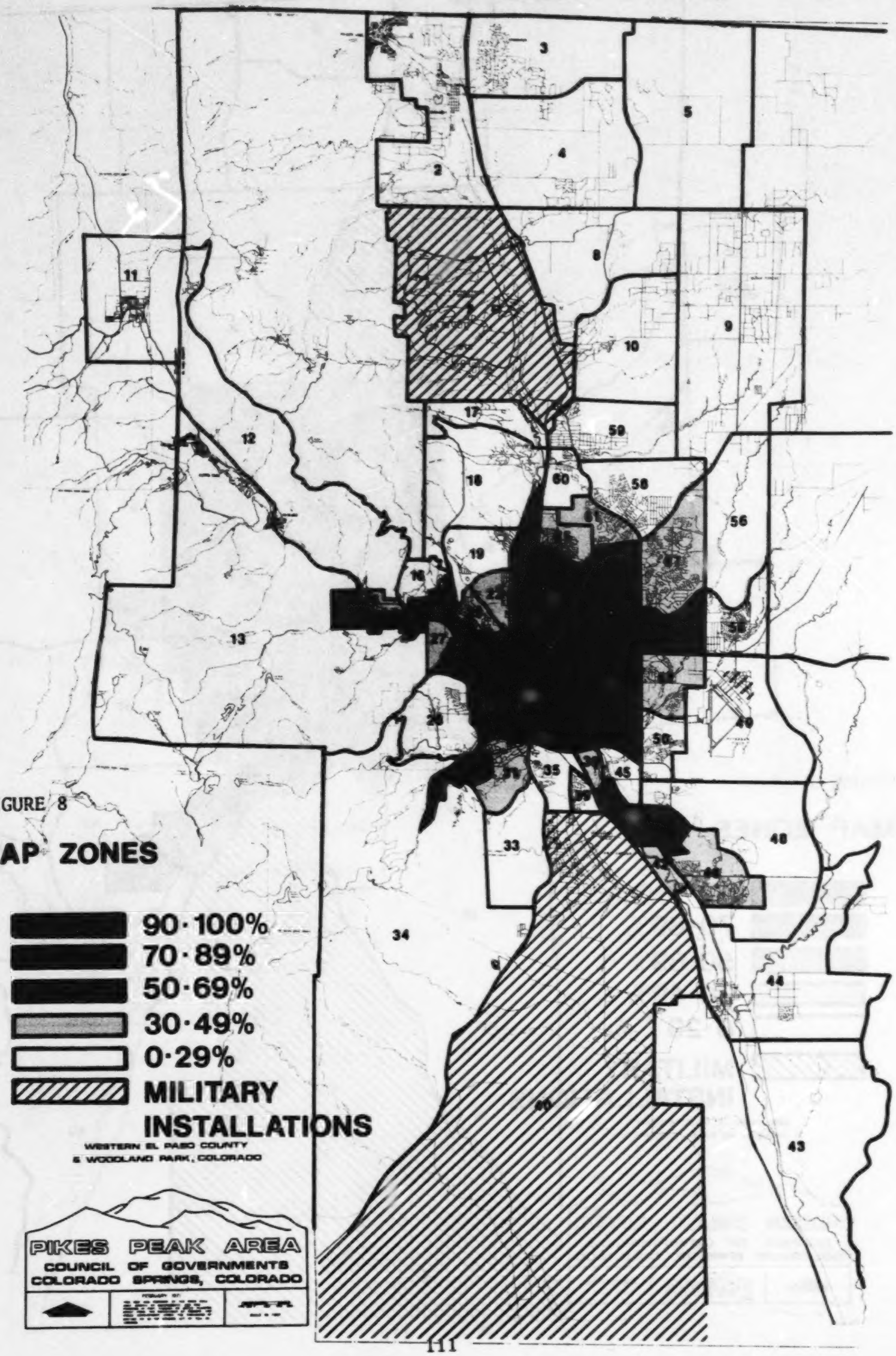
- 550,000 people in area by year 2000
- 210,000 employees in area by year 2000
- Similar residential and other development densities as today
- Utility service area expanded on demand
- No limits on annexation.

Following the evaluation of these options, a fifth option called the "Feasible Option" was constructed which seemed to best reflect the policies preferred by government members of the PPACG. This option assigns priority to growth within the central urbanized area, but not to the exclusion of other areas. Outlying communities would also program growth within the fiscal, environmental, and physical limits of each of the communities. Implicit in the consideration of these development policies is some limitation of rural densities to preserve a greater identity for existing communities within the region, to limit the cost of infrastructure, and to control the environmental impacts of development. The following general guidelines summarize the "Feasible Option":

- Plan for an area population of 550,000 persons by the year 2000;
- Place emphasis on using the natural environmental constraints as a means of guiding growth;
- Continue attempts to obtain citizen participation;
- Continue to place more emphasis on public transportation as part of the transportation plan;
- Aim planning at providing implementation tools and information services;
- Preserve the identity of the individual communities that make up the Pikes Peak Region.

The development impact of this scenario is summarized in Figures 8 and 9. The emissions impact of these scenarios is summarized in Table 1. A summary of the concentration and human exposure consequences of these alternatives or options is summarized in the "Plan Analysis" section of Chapter III. This analysis points to the conclusion that the future design of transportation and land use systems will act to ameliorate expected pollution problems within the Pikes Peak Region. However, they will not be sufficient in themselves to attain and maintain air quality within the Region, and more specific control strategies will need to be included as part of the maintenance plan and the transportation control element.

Percent Developed 1973


3
5
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2
8
9
10
11
17
59
12
60
58
18
56
19
13
27
26
35
45
50
49
33
48
34
44
40
43
90·100%
70·89%
50·69%
30·49%
0·29%
MILITARY INSTALLATIONS
WESTERN EL PASO COUNTY
& WOODLAND PARK, COLORADO
PIKES PEAK AREA
COUNCIL OF GOVERNMENTS
COLORADO SPRINGS, COLORADO

FIGURE 8

MAP ZONES

Percent Developed 2000

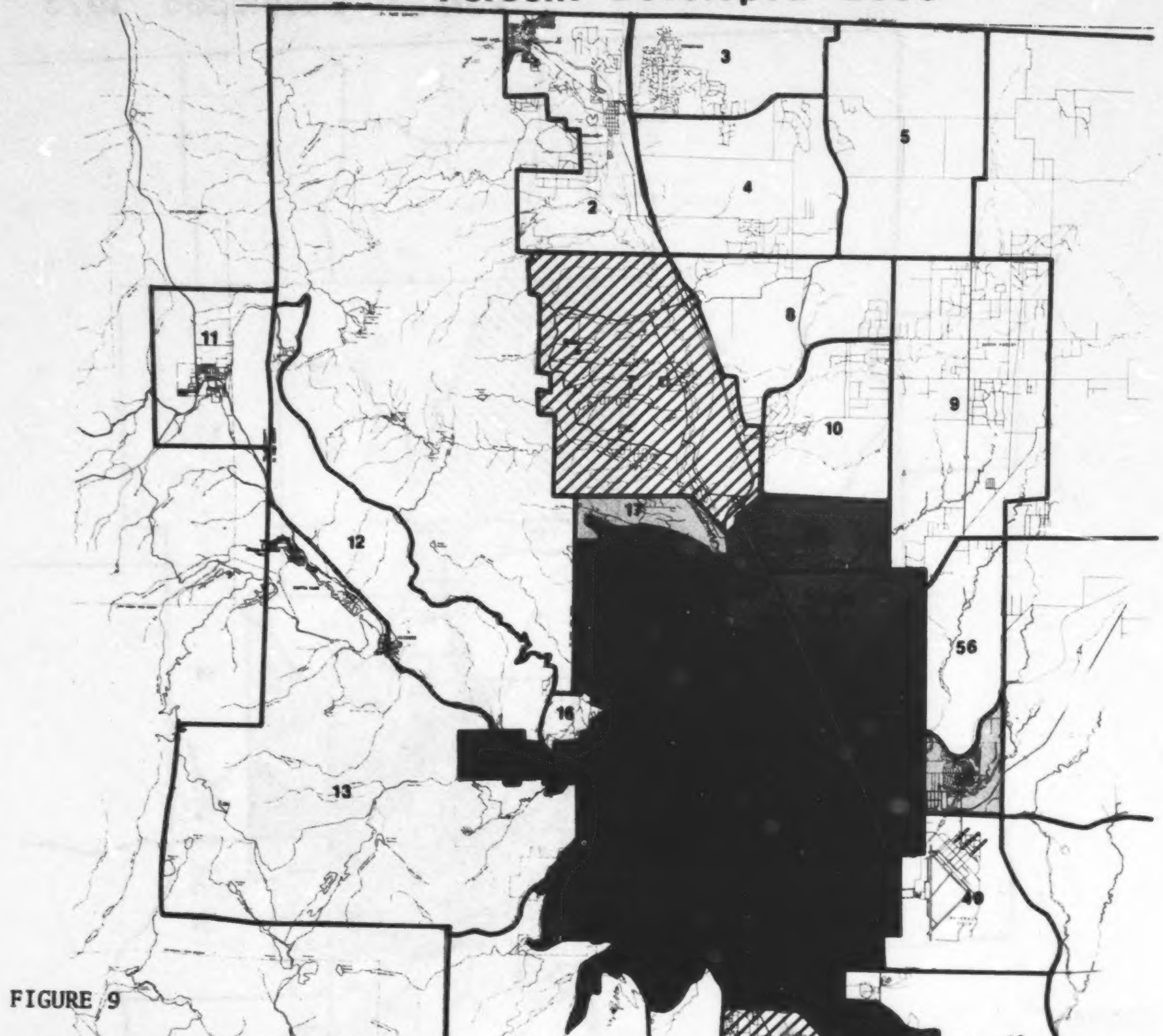

FIGURE 9

MAP ZONES
90·100%
70·89%
50·69%
30·49%
0·29
MILITARY INSTALLATIONS
WESTERN EL PASO COUNTY
& WOODLAND PARK, COLORADO
PIKES PEAK AREA
COUNCIL OF GOVERNMENTS
COLORADO SPRINGS, COLORADO
2
3
4
5
8
9
10
11
12
13
16
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48
56

APPENDIX D

REGIONAL IMPACT ANALYSIS OF GRADING CONTROLS

The following analysis is intended to serve as an illustration of the research methods discussed in Chapter IV. Obviously the impact analysis for each metropolitan area will vary substantially depending on local environmental conditions, the availability and cost of data sources, the amount of manpower assigned to the product, the volume of documentation needed to satisfy local decision makers, and other factors. It should also be noted that the research methodology outlined in Table 3 does not apply equally well to all air quality control measures. It is particularly orianted to transportation system changes, since it can be expected that most metropolitan areas will be concerned to a substantial degree with automotive emissions and the design of transportation control plans.

In order to demonstrate the range of analyses one may be expected to construct, a control measure is evaluated here that does not fit well with the transportation related analyses: grading controls. By doing so, the point can be emphasized that impact analyses will not necessarily fit a single framework such as the one outlined in Table 3, and the researcher will be called upon to adapt the methodology to suit the demands of his particular project.

In general, a grading ordinance sets forth standards and regulations to control excavation, grading, drainage, and earthwork construction, including fills and embankments. The ordinance also establishes the administrative procedures for issuance of permits, and provides for approval of plans and inspection of grading construction. It is the purpose of such an ordinance to protect and safeguard property and public welfare, to prevent nuisance and pollution by blowing dust, and to encourage the protection of attractive natural features within the region.

The following analysis considers the application of grading controls to the City of Colorado Springs. Such controls are particularly appropriate for the control of particulate pollution in the Pikes Peak Region, because of the arid climate, the fine grained soils and the limited productivity of native vegetative species. The first and fourth quarters of the year also experience frequent periods of high winds, including occasional Chinooks. Conservation measures aimed at reducing wind erosion problems, therefore, will have measurable impact on the reduction of ambient concentrations of particulates.

Air Quality Impact

The impact of a grading ordinance on air quality for any given year can not be determined precisely. The factors which bear on year to year changes in concentrations are related to the following:

1. Amount of land developed in a given year.
2. Amount of land subject to other grading regulations, e.g., Veterans Administration minimum property standards, State regulations.
3. Control methods used by developers.

4. Density of development subject to ordinance and amount of impervious surfaces.

5. Distribution of development activities within control area.

6. Yearly meteorological variations.

Once certain assumptions and estimates are made, however, a relative picture of the expected impact can be constructed. For the El Paso County Air Quality Maintenance Area, the following assumptions were made:

Amount of land developed in Colorado Springs per year: 300 acres, based on inventory of developed land between 1974 and 1977.

Percent of land subject to ordinance: 40% based on very limited data.

Emission factor for grading activities (earthmoving equipment and traffic on exposed earth): 0.98 Ton/acre/month[40]

Control Efficiency: 50%.[41]

Average duration of projects: 6 months.

Given these factors, the amount of uncontrolled and controlled emissions from grading operations can be given by the following formulas:

$E_u = e\ t\ k\ A$

$E_c = e\ t\ k\ A\ (1 - \frac{C}{100})$ Where

E_u = total uncontrolled emissions, tons/year

E_c = total emissions, with application of grading controls, tons/year

t = duration of project, in months

k = percent of developing land subject to ordinance

A = acreage developed in control area per year

C = control efficiency of grading controls.

e = emissions factor, tons per acre per month

Using these formulas, one finds that application of the grading controls will reduce particulate emissions from 705 tons per year to 353 tons per year for those land areas subject to the grading controls. The approximate emission total from all sources within the city limits of Colorado Springs is 5,700 tons per year; the application of grading controls would reduce total emissions by approximately 6%, therefore.

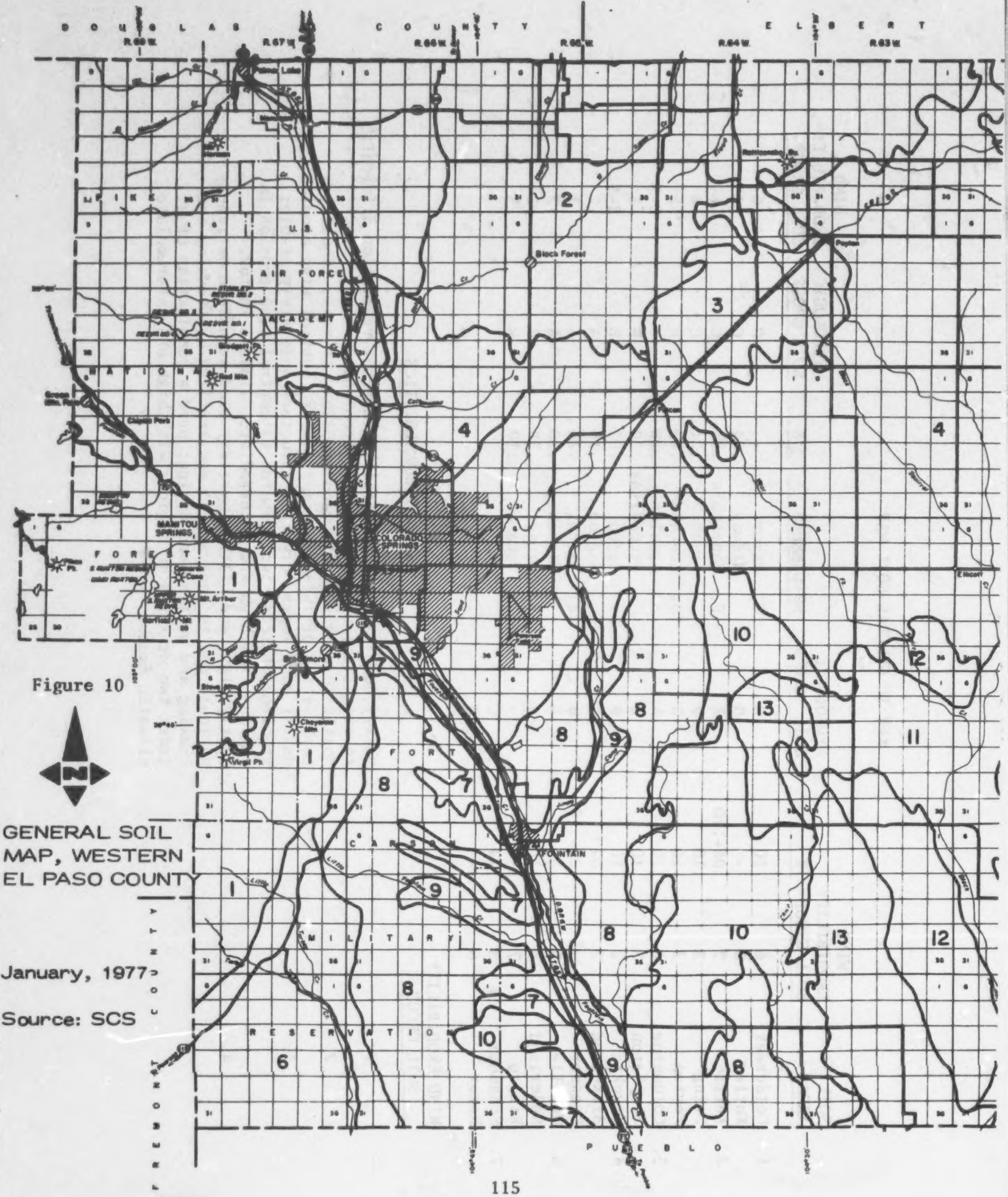
DOUGLAS COUNTY
ELBERT
R.68W.
R.67W.
R.66W.
R.65W.
R.64W.
R.63W.
PIKE NATIONAL FOREST
U.S. AIR FORCE ACADEMY
Palmer Lake
Black Forest
Peyton
Falcon
Ellicott
MANITOU SPRINGS
COLORADO SPRINGS
Broadmoor
Cheyenne Mtn.
FORT CARSON MILITARY RESERVATION
FOUNTAIN
FREMONT COUNTY
PUEBLO
N
1
2
3
4
6
7
8
9
10
11
12
13

Figure 10

GENERAL SOIL MAP, WESTERN EL PASO COUNTY

January, 1977

Source: SCS

KEY TO GENERAL SOIL MAP

	SOIL AREAS	WIND ERODIBILITY SOIL GROUP	K	HYDROLOGIC SOIL GROUP
1.	Coldcreek	6	.10	B
	Kutler	8	-	D
2.	Kettle	2	.05-.10	B
	Pring	3	.10	B
	Peyton	2	.10	B
3.	Columbine	6	.10	A
	Stapleton	3	.10	B
4.	Truckton	2	.10	B
	Blakeland	2	.02	A
	Bresser	2-3	.02-.10	B
6.	Neville	3	.30	B
	Nederland	8	.10	B
	Rizozo	7	-	-
7.	Schamber	8	.24	C
	Razor	6	-	D

	SOIL AREAS	K	HYDROLOGIC SOIL GROUP	WIND ERODIBILITY SOIL GROUP
8.	Razor	-	D	6
	Midway	.24	C	4
9.	Manzanola	.24	C	6
	Limon	.24	C	4
10.	Stoneham	.20	B	5
	Ascalon	.28	B	2-3
	Ft.Collins	.20	B	5
11.	Bijou	.02	B	2-3
	Wigton	.10	A	2
12.	Valent	.15	A	1
	Wigton	.10	A	2
13.	Olney	.28	B	2
	Vona	.10	B	3

WIND ERODIBILITY SOIL GROUP	SOIL CHARACTERISTICS
1.	Mostly dune sand; single grain structure; vegetation difficult to establish; not suitable for cropland.
2.	Mostly loamy sands; dry clod structure is weak; requires a combination of intensive practices to control wind erosion.
3.	Mostly sand loams; dry clod structure moderately stable; requires at least two measures to control wind erosion in regions with high and intermediate climatic factor.
4.	Mostly clays and silty clays; dry clod structure extremely variable due to contraction and swelling by freezing and thawing and wetting and drying; need a combination of at least two measures in regions with high and intermediate climatic factor.

Key to General Soil Map, Continued

WIND ERODIBILITY SOIL GROUP	SOIL CHARACTERISTICS
5.	Mostly loams and sandy clay loans; dry clod structure quite stable; a combination of at least two measures in region with high climatic factor.
6.	Mostly silt loams and clay loams; dry clod structures stable; require a combination of at least two measures in a region with high climatic factor.
7.	Mostly silty clay loams; dry clod structure extremely stable; usually a single practice is sufficient to control wind erosion.
8.	Soils not suitable for crops because of wetness, stoniness, etc.

EROSION: The danger of accelerated erosion is related mainly by soil slope, permeability and texture. The columns listed under erosions factors are: K factor = the erosion hazard rating for bare soil. The "K" is used to indicate the relative degree of susceptibility to erosion. The higher the "K" value the greater the risk of erosion occurring from bare soil.

HYDROLOGIC SOIL GROUPS: Hydrologic soil groups are based on the amount of runoff from bare soil after prolonged wetting. Soils with rapid permeability rates generally yield lower runoff than soils with slow permeability. Soils with high infiltration rates permit small runoff because most of the precipitation being added to the soil is transmitted to the subsoil and substrata.

Soils are placed into four broad hydrologic classes. These are:

Key to General Soil Map, Continued

Hydrologic Group A:	Includes soils from which there is little runoff. With high infiltration rates and rapid permeability, much of the rain fall that occurs moves into and through the soil. Soils included in this group are sandy or gravelly, well-drained or excessively well-drained soils. Except in very high intensity storms, the amount of runoff is relatively low.
Hydrologic Group B.	Soils from which there are moderate amounts of runoff. Soils generally have slow infiltration rates and slow permeability rates. Soils generally included in this group are somewhat poorly drained or moderately well drained, with seasonal fluctuating high water tables or with perched water tables caused by impermeable layers in the lower part of the soil.
Hydrologic Group D.	Includes soils with very large amounts or runoff. Most water that falls on these soils is lost to runoff. Soils generally included are very shallow soils to bedrock and poorly and very poorly drained soils or soils having very low permeability in the subsoil. Rainfall becomes excess water that cannot be absorbed by the soil for the reasons stated above, thus is lost to runoff.
Erodibility:	Erodibility is the wind erosion group as defined in the Guide for Wind Erosion Control on Cropland in the Great Plains States, July 1964; supplemented by Colorado Agronomy Note #49, August 1974.

It should be noted that the emission factor used in this analysis takes into account only those emissions resulting from the earthmoving equipment and vehiclular traffic on exposed soil. The source footnoted here did not consider emissions from wind erosion to be a significant factor, and they were not included in the emission factor. Within the Pikes Peak Region however, the Soil Conservation Service has estimated the soil loss from wind erosion from denuded soils may exceed 60 tons per year for soils characteristically found in the urbanized area. This loss would include soils of larger particle sized than would become air-borne for long enough periods to be detected by particulate monitors; at present, the SCS has no conversion factor that would allow one to calculate the fraction of total soil loss that could be considered to be respirable. Grain sizes of local soils have been measured, however, and one finds that between 15% and 35% of Truckton, Blakeland, and Bresser soils (those predominately found in the metro area) will pass the smallest sieve; this sieve is .074 mm in diameter (74 microns). Assuming all the soils passing through this sieve would be picked up by a particulate monitoring network, the emission factor would approximately double for the Colorado Springs metropolitan area if one were to take into account emissions from wind erosion.

This factor is an important one, since grading ordinance typically are oriented more to the control of soils disturbed or denuded by grading than they are to the control of vehicular emissions during construction. One finds that it is common for areas to be graded in anticipation of development; it is also the case that development does not always occur on the schedule anticipated and soils may be left exposed for much longer than six months used as an estimate of construction time. Conservation measures to control wind erosion are equally important in the Pikes Peak Region as are controls for vehicular movement during grading operations, therefore, and the 6% reduction might be considered a conservative estimate of the reduction in particulate emission that can be expected from the application of a grading ordinance.

Water Quality Control

The grading ordinance was selected for adoption,in part, because it provided the opportunity to satisfy both air quality and water goals. The ordinance will provide for the control of wind erosion in developing areas within the urbanizing by the application of conservation measures that have been developed by the Soil Conservation Service, the EPA, the State Highway Department, and other agencies for Colorado. One finds that these same control measures can be correlated with the control of both runoff and soil loss.

Soil loss from non-irrigated land is calculated using the Universal Soil Loss Equation. The estimated soil loss is that caused by water erosion, and accounts only for sheet and rill erosion; it does not account for gully erosion. The soil loss equation is given by:

TABLE 11
AVERAGE FACTOR C VALUES FOR VARIOUS SURFACE STABILIZING TREATMENTS

Treatment	Factor C Values for Time Elapsed Between Seeding and Building None*	 6 months**
Seed, fertilizer and staw mulch. Straw disked or treated with asphalt or chemical straw tact.	0.35	0.23
Seed and fertilizer	0.64	0.54
Chemical (providing 3 months protection)	0.89	--
Seed and fertilizer with chemical (providing 3 months protection)	0.52	0.38
Chemical (providing 12 months protection)	0.56	--
Seed and fertilizer with chemical (12 months protection)	0.38	--

*Assumes 18 month construction period. **Assumes 24 month construction period.

TABLE 12
EFFECTIVENESS OF GROUND COVER ON EROSION LOSS AT CONSTRUCTION SITES

Kinds of Ground Cover	Soil Loss Reduction Related to Bare Surfaces (Percent Effectiveness)	C
Seedlings		
Permanent Grasses	99	.01
Ryegrass (Perennial)	95	.05
Ryegrass (Annual)	90	.10
Small Grain	95	.05
Millet & Sudangrass	95	.05
Field Bronegrass	97	.03
Grass Sod	99	.01
Hay (2 tons per Acre)	98	.02
Small grain straw (2 tons per Acre	98	.02
Corn residues (4 tons per Acre)	98	.02
Wood chips (6 tons per Acre)	94	.06
*Wood Cellulose Fiber (103/4 tons per Acre)	90	.10
**Fiberglass (1,000 lbs per Acre)	95	.05
**Asphalt Emulsion (12- gal per Acre)	98	.02

*Based on full established stand. **Experimental-not fully validated.

Reference: "Comparative Costs of Erosion and Sediment Control,
Construction Activities", EPA-430/9-73-016, July 1973

TABLE 13
PROMISING CONTROL SYSTEM AND EFFECTIVENESS

System Numbers	Components	Percent Effectiveness	C & P
1	Seed, fertilizer, straw mulch. Erosion structures (normal). Sediment basins (0.04 ratio, and 70 percent of area)	91	.09
2	Same as (1) except chemical (12 months protection) replaces straw	90	.10
3	Same as (1) except chemical straw tack replaces asphalt	91	.09
4	Seed, fertilizer, straw mulch. Diversion berms. Sediment basins (0.04 ratio and 100 percent area)	90	.10
5	Seed, fertilizer, straw mulch. Downstream sediment basin (0.06 ratio)	93	.07
6	Seed, fertilizer, chemical (12 months protection). Downstream sediment basin (0.06 ratio)	92	.08
7	Seed, fertilizer, straw mulch. Downstream sediment basin using flocculants.	96	.04
8	Same as (7) without straw mulch	94	.06
9	Chemical (12 months protection) sediment basin using flocculants	94	.06
10	Same as (9) with seed, fertilizer	96	.04

Reference: "Comparative Costs of Erosion and Sediment Control, Construction Activities", EPA-430/9-73-016, July 1973

$A = A_i \ (R\ K\ L\ S\ C\ P\ S_d)$

Where:
A = the soil loss in tons per year per given area
R = rainfall factor
K = soil erodibility factor; the higher the K value, the greater the risk of erosion occuring from bare soil, See Figure 10 for description of regional soil types.
L = lenth of slope
S = percent slope
C = cropping management factor
P = erosion control practice factor, including control structures.
S_D = sediment delivery ratio
A_i = land use acreage

Tables 11 through 13 show the C values from the equation above that correspond to various conservation practices. These C values are average figures and have not been specifically determined based on local conditions. Instead, local conditions are primarily reflected in the description of soil characteristics; these characteristics are summarized for purposes of evaluating soil loss from water is the K factor. Figure 10 provides a general soils map of western El Paso County, and the soil map key lists the K values for each of the major soil types.

Given the type of particulate control measures employed on a site graded for development and the site's soil characteristics, the expected reduction in soil loss from water erosion can also be calculated. Assume, for example, that an acre of land from the Blakeland soil series has been graded for development. Further assume that a 10% slope remains which runs for 300 feet (representative depth for a one acre residential lot). If seed and fertilizer have been drilled traveling across the slope, the expected soil loss from water erosion can be calculated.

R = 70 average rainfall value for El Paso County
K = .02 value for Blakeland series, from the soil map key
LS= 2.37 (10% slope and 300 feet length[42]
C = .54 seed and fertilizer
P = .8 (cross slope farming)[43]
S_d= .7 [44]
A_i= 1 acre

Therefore, $A = 1\ (70 \times .02 \times 2.37 \times .54 \times .8 \times .7)$
or $A = 1$ ton per acre per year from water erosion

Soil loss from relatively simple conservation measures can, therefore, be reduced to one to five tons per year depending on the K value of the principal soil associations in the urbanized area (Blakeland, Bresser and Truckton.

Runoff

Particulate control measures can also be expected to reduce the runoff of water from urban development sites. In addition to the retention of soil, controlling the loss of water will reduce the burden on storm drainage systems and reduce future costs for drainage improvements, will provide additional waters for ground water recharge, will increase the productive capacity and aesthetic value of the vegetative cover, and will reduce the potential for damage to adjacent property owners.

Tables 14 and 15 relate land use and conservation practices to the volume of runoff. The soil map key also provides the interpretation of regional soils in terms of their hydrological characteristics. Using these tables, one finds that for a one inch rain, runoff can be reduced to approximately .1 inch if conservation measures are applied to the soils with the highest runoff rates (D soils). For soils with more rapid percolation (A group), runoff can virtually be eliminated from a one inch rain through conservation. techniques. (See Table 15)

These considerations will have a particularly important impact on the foothills area of the metropolitan area. While these areas generally have a richer set of terrestrial features than the plans area, they are also more subject to disruption from erosion as a result of development activities. The uniform application of conservation measures will work to guarantee that these resources are preserved and maintained, and that the burden on drainage and stream systems will be minimized.

Water Use

Dust controls during construction operations and revegetation efforts may require greater amounts of water than would be the case without grading controls. Spraying of dirt tracts during construction and hydromulching of denuded soils represent two examples of stabilization techniques which may require substantial amounts of water.

These practices could be monitored during the implementation phase to ensure that increased water consumption does not unnecessarily burden community water supplies. In general, one would expect that short term increases in water consumption would be more than offset by decreases in water runoff provided over the long-term future through the application of conservation techniques.

Table 14 Runoff curve numbers for selected agricultural, suburban, and urban land use.[45]

LAND USE DESCRIPTION			HYDROLOGIC SOIL GROUP			
			A	B	C	D
Cultivated land:	without conservation treatment		72	81	88	91
	with conservation treatment		62	71	78	81
Pasture or range land:	poor condition		68	79	86	89
	good condition		39	61	74	80
Meadow:	good condition		30	58	71	78
Wood or forest land:	thin stand, poor cover, no mulch		45	66	77	83
	good cover		25	55	70	77
Open spaces, lawns, parks, golf courses, cemeteries, etc:	good condition: grass cover on 75% or more of the area		39	61	74	80
	fair condition: grass cover on 50% to 75% of the area		49	69	79	84
Commercial and business areas (85% impervious)			89	92	94	95
Industrial districts (72% impervious)			81	88	91	93
Residential:	Average Lot Size	Average % Impervious				
	1/8 acre or less	65	77	85	90	92
	1/4 acre	38	61	75	83	87
	1/3 acre	30	57	72	81	86
	1/2 acre	25	54	70	80	85
	1 acre	20	51	68	79	84
Paved parking lots, roofs, driveways, etc.			98	98	98	98
Streets and roads:	paved w/curb and storm sewers		98	98	98	98
	gravel		76	85	89	91
	dirt		72	82	87	89

Table 15 Runoff Depth in Inches for Selected CN's and Rainfall Amounts[46]

Rainfall (inches)	Curve Number (CN)[1]								
	60	65	70	75	80	85	90	95	98
1.0	0	0	0	0.03	0.08	0.17	0.32	0.56	0.79
1.2	0	0	0.03	0.07	0.15	0.28	0.46	0.74	0.99
1.4	0	0.02	0.06	0/13	0.24	0.39	0.61	0.92	1.18
1.6	0.01	0.05	0.11	0.20	0.34	0.52	0.76	1.11	1.38
1.8	0.03	0.09	0.17	0.29	0.44	0.65	0.93	1.29	1.58
2.0	0.06	0.14	0.24	0.38	0.56	0.80	1.09	1.48	1.77
2.5	0.17	0.30	0.46	0.65	0.89	1.18	1.53	1.96	2.27
3.0	0.33	0.51	0.72	0.96	1.25	1.59	1.98	2.45	2.78
4.0	1.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
5.0	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
5.0	1.92	2.35	2.80	3.28	3.78	4.31	4.85	5.41	5.76
7.0	2.60	3.10	3.62	4.15	4.69	5.26	5.82	6.41	6.76
8.0	3.33	3.90	4.47	5.04	5.62	6.22	6.81	7.40	7.76
9.0	4.10	4.72	5.34	5.95	6.57	7.19	7.79	8.40	8.76
10.0	4.90	5.57	6.23	6.88	7.52	8.16	8.78	9.40	9.76
11.0	5.72	6.44	7.13	7.82	8.48	9.14	9.77	10.39	10.76
12.0	6.56	7.32	8.05	8.76	9.45	10.12	10.76	11.39	11.76

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[1] To obtain runoff depths for CH's and other rainfall amounts not shown in this table, use an arithmetic interpolation, or Appendix C in Reference 4.

Energy Use

The application of grading controls will marginally increase the amounts of energy needed to develop sites in the urban area. These increases will be related to the production, transport, and application of materials used as conservation measures. The amount of additional resources committed will vary substantially depending on the site and the conservation measures used, and will range from seeding with native grasses to the construction of cement or asphalt drainage structures. These increases could be measured on a site by site bases; estimates have not been included here, since they can be considered to be a relatively small fraction of the amounts of fuel and other energy resources accounted for by construction equipment, trucking, laborer commuting, and other operations associated with land development. On a regional scale, the amounts of additional resources committed are essentially insignificant.

Transportation System Impacts

Local grading ordinances fit well with transportation planning goals. Conservation measures, by reducing the volume of runoff that reaches the storm drainage system and area streams, will also reduce future drainage improvements required as part of transportation system development, e.g., bridges, culverts, and other structure. By controlling the amount of sediments reaching local streets, grading controls will also reduce the burden on drainage systems, will reduce clogging and other maintenance costs, and provide a safer and smoother running surface.

Noise Impacts

Noise impacts associated with the grading ordinance will be minimal. However, to the extent that landscaping vegetative productivity near street systems, one could expect a greater buffering effect and a reduction of noise penetration. If grading plans were specifically coordinated with buffering elements such as berms, shelter belts, and other landscaping elements, the potential for reducing noise impacts would increase substantially. No such coordination is envisioned as a mandatory requirement of the grading ordinance, so benefits that accrue from such planning will depend on the initiative of individual developers.

Private Sector Costs

Costs for implementing the grading ordinance will vary substantially depending on a number of factors. Most local communities already include requirements within subdivision and zoning ordinances for handling storm drainage. In addition, the minimum property standards used by VA and FHA also require control of grading if a subdivision is to be eligible for federal housing loan programs. In the state of Colorado, State regulations already apply to grading where more than five acres are to be disturbed. In general, costs will need to be determined on a site by site basis and will vary according to the following factors:

1. topographical and drainage characteristics of the site
2. land use and density of development proposed for site
3. soil characteristics
4. type of control measure, e. g. sodding versus seeding
5. sensitivity of adjacent properties, e.g. proximity to surface waters.

The most basic conservation practice for level sites would consist of seeding the disturbed ground with drought resistant grasses; this would cost approximately $35 to $45 per acre and would include the cost of seed, fertilizer, land preparation, equipment use, and labor. Other methods for the stabilization of cut and fill slopes and other site features would cost more, depending on the methods and materials used. Table 16 provides a list of erosion control measures used by the Colorado Department of Highways and average bids received in 1977 for the application or installation of these controls.

Control of fugitive dust associated with the operation of equipment and movement of vehicles during actual grading operations can be estimated based on the costs of labor and equipment use. Current estimates are difficult to drive, however, since constructions bids do not normally provide costs by type of vehicle or operation, e.g., water truck operation. In addition, costs would vary substantially with the scheduling of development. If road surfaces were graveled or paved immediately after grading and compaction, additional controls for futitive dust would not be necessary in order to control vehicular emissions. On the other hand, if roads were roughed in but not completed, the costs for controlling fugitive dust on these surfaces from heavy equipment and trucks would be substantial. One would expect, at the least, more careful development planning in order to minimize the costs associated with temporary controls related to heavy vehicles.

Public and Private Benefits

Balancing the ledger on the benefit side in dollar terms is more difficult in many ways than the evaluation of costs. How does one measure, for example, the value of an improved quality of life or the reduced risk of disease? What trade-offs are individuals in this region willing to make? How do the risks of air pollution compare with risks we voluntarily expose ourselves to daily? Because of this difficulty, Chapter V emphasized that the evaluation of social impacts must take into account not only the results of any attempts at quantitative evaluation, but must include the broader implications of public opinion, industry pressures, and the predilection of local decision makers. In general, however, both the public and private sectors will benefit from strict adherence to air quality standards, and these benefits can be summarized as follows:

TABLE 16

EROSION CONTROL MEASURES ACCOMPANYING GRADING AND THEIR COSTS

Erosion Control Measure	Average Bid Received by Colorado Department of Highways in 1977
Soil preparation, native habitat	$ 17.97 per acre
Soil preparation, lawns	$525.16 per acre
Sodding	$ 0.20 per square foot
Mulching	$150.00 per acre
Hydro-mulching	$449.00 per ton
Mulch netting	$ 0.48 per square yard
Soil retention blanket, jute	$ 1.00 per square yard
Soil retention blanket, paper	$ 1.10 per square yard
Tree grate	$310.00 per acre
Light rip rap	$ 11.63 per cubic yard
Heavy rip rap	$ 15.74 per cubic yard
Concrete slope and ditch paving	$127.98 per cubic yard
Concrete slope and ditch paving, reinforced	$129.69 per cubic yard
Dry rubble slope and ditch paving	$ 19.40 per cubic yard
Grouted rubble slope	$ 66.58 per cubic yard
Bituminous slope and ditch paving	$ 29.43 per ton
Plastic lined ditch	$23.00 per lineal foot

Public Benefit

1. Improved health
2. Reduced safety hazards
3. Reduced health risks to man and animal
4. More comfortable enjoyment of life and property
5. Reduced property damage
6. Increased property values
7. Less vegetation damage

Private Benefits

1. Lower employee absenteeism
2. Reduced risk of civil damage suits
3. Better employee relations
4. Better public relations
5. Reduced Maintenence costs
6. Increased property values
7. Product recovery
8. New markets for new products relating to air pollution control
9. Reduced product contamination or damage.[47]

Within the Pikes Peak Region, a number of characteristics of the economy would expand this list. Tourism, though no longer a major component of the Regional economy is still a significant sector and accounts for approximately 10% of total retail sales. The continued viability of this industry will depend largely on the conservation of those natural features that attract tourists from throughout the nation.

The Pikes Peak Region also serves as retirement community for a large number of families, particularly military retirees. These families contribute to the local economy through additional demand in housing and retail trade sectors. Should pollution problems continue to worsen, retired and elderly families will be particularly affected, and the area's ability to attract new families will be substantially lost.

A third local industry that is of major importance and also partially dependent on regional health factors is the military. Fort Carson and the Air Force Academy, particularly, are responsible for the physical conditioning and training of military forces. Individuals who are physically active breathe much larger amounts of ambient air and are, therefore, much more susceptible to the debilitating effects of air pollution. Should pollution problems remain unchecked, these institutions will also need to reevaluate their long term plans for training in the Pikes Peak Region.

Finally, it is worthwhile to point out that local efforts to develop the Region as an amateur sports center would be seriously affected by continued air pollution problems. Certainly, the Colorado Springs area could not be considered an appropriate locale for a permanent olympic training facility, if athletes were required to live and train in physically damaging accumulations of air pollution.

Social Impacts

The principal social benefits derived from a reduction of particulate concentrations to the Federal ambient standard of 75 micrograms per cubic meter are associated with human health. The effects of particulates on human health depend on the size and chemical composition of the materials that are absorbed by the body (principally through the lungs). Particulates that are essentially inert chemically may harm the lungs by irritation of the muscle structure, by causing swelling of membranes lining the airways, and by enlargement of the glands that produce mucus. Chronic effects related to inert particulates are related to progressive scarring of the lungs which interferes with proper gas exchange. Acute effects can also be experienced when materials reach the air cells (alveoli); the irritation of particulates may result in collapse of the alveoli or the alveoli may become filled with edema fluid. In either case, the damaged air cells can not ventilate properly and serious physiological damage may result.

Inert materials are damaging to the lungs not only by acting as an irritant, but aerosol particules also have the property to absorb other materials on their surface. Research has demonstrated for example, that the effects of inhaled gases such as SO_2 are compounded by the catalytic or transport effect of inert aerosols.

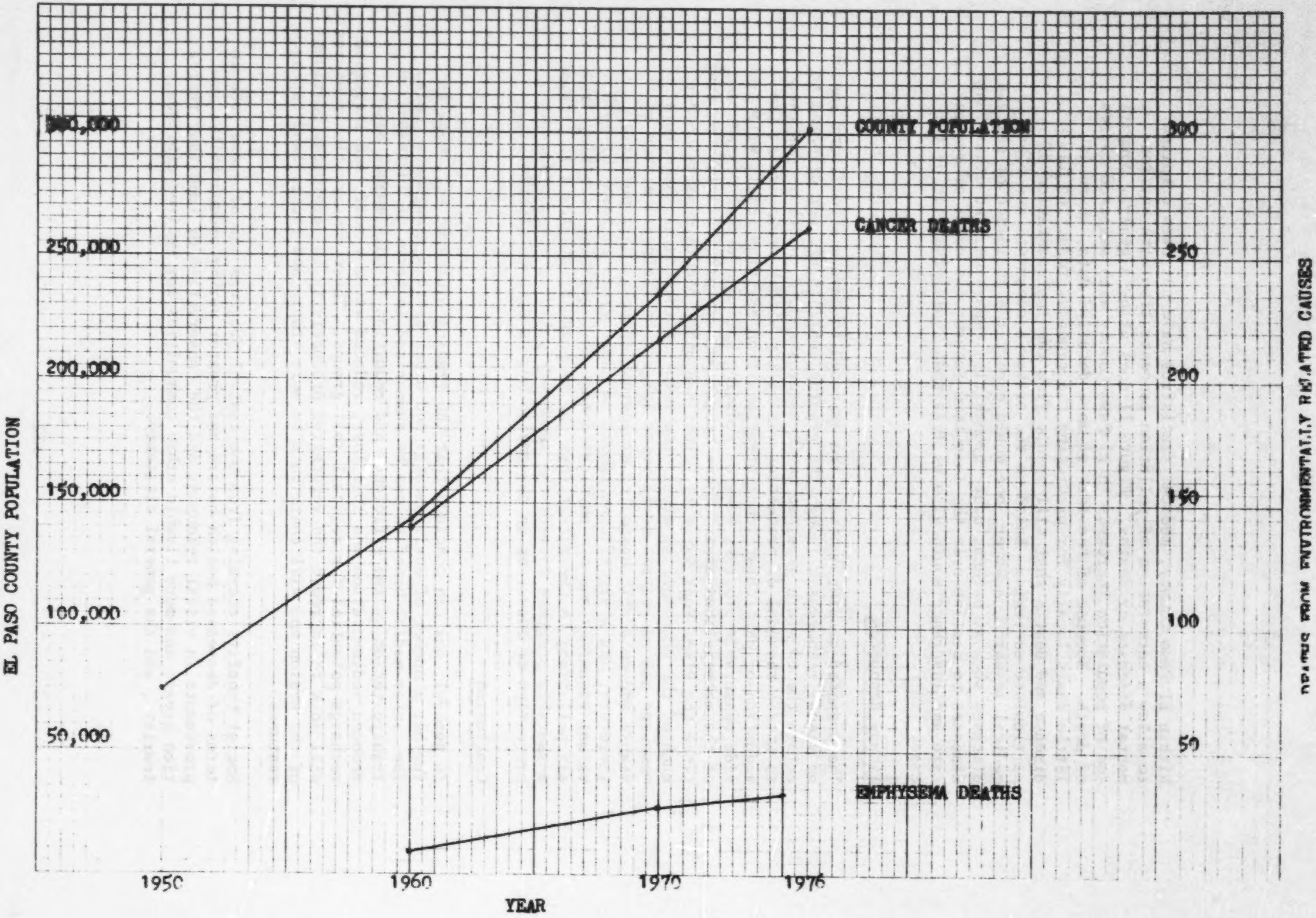
Particulates are particularly damaging to persons with lung diseases such as asthma or bronchitis. These persons typically react to inhaled irritants at a dosage which could be expected to have no effect on healthy individuals. In addition, further narrowing of airways by inhaled irritants in patients who already have constricted airways would have more serious consequences than it would in healthy individuals.

In addition to inert materials, particulates also include a wide range of other materials that are chemically reactive and which may act as teratogens (agents causing physical defects in a developing embryo), mutagens (capable of inducing mutation) and carcinogens (cancer producing). These pollutants include asbestos, lead, nickel, chromates, arsenic, vanadium, chlorinated hydrocarbons, coal products, and other polynuclear organic compounds. Substances such as lead may also cause neurologic damage and may be most seriously damaging to children through the poisening of red blood cells, slowing of nerve reaction, reduction in muscular strength, and reduction in IQ. Particulates that result from the incomplete combustion of fossil fuels, particularly coal, pose specific threats; polynuclear hydrocarbons seem to be especially effective carcinogens among this class of products; and one of these that is used by many laboratories as a tracer for such carcinogens is 3,4-benzphyrene.[48]

In terms of mass concentrations, the "Air Quality Criteria for Particulate Matter"[49], indicates effects were observed at particulate concentration of 80 $\mu g/m^3$ through increased incidence of death for persons over 50 years of age. At annual average levels of 100 $\mu g/m^3$, children are likely to experience increased incidence of respiratory disease. At a particulate level of 60 $\mu g/m^3$, in the present of sulfur oxides and moisture, there is accelerated corrosion of steel and zinc.

FIGURE 11

ENVIRONMENTAL DISEASES AND POPULATION GROWTH IN EL PASO COUNTY



Within El Paso County, medical statistics have not been compiled to allow a correlation of pollution concentration with environmental diseases or deaths. Figure 11 does allow a general comparison of population increases in El Paso County with selected causes of death. Because of the lack of more detailed data, there is little basis locally for predicting the expected reduction in disease and deaths that will result from the implementation of particulate controls. Based on the criteria documents and other medical research, however, one would expect the incidence of certain diseases such as asthma, acute bronchitis, emphysema, and other lung diseases to decline over the long term future; the costs of medical care and insurance would also be less than would otherwise be the case.

Visual Resources

The proposed grading controls are expected to have a significant impact on visual resources. Though the grading controls are not directed to attain the 60 micro gram per cubic meter standard, which is designed to attain the goal of protecting visibility within urban areas, the reduction of particulate concentrations from existing levels will provide measurable progress towards reducing haze and visual degradation of the metropolitan area. These reductions are particularly important since the Pikes Peak National Forest and other mountain parks border much of the metropolitan areas; the value of these areas as natural resource and recreation areas rests largely on their protection as viable and relatvely unspoiled ecological systems. Air pollution, therefore, has a significant impact on these areas in terms of both visual resources and the physical damage to vegetation resulting from air pollution; to the extent that the proposed strategies will provide measurable progress towards the secondary pollution standards, the protection of resources in the entire Region will be afforded.

Conclusion

In general, one can conclude that the grading ordinance will work to further a number of environmental and urban systems management goals. The "inter-media" benefits can be summarized in terms of increases in transportation system efficiency and reduction in maintenance costs, reduced sedimentation and soil loss, reduced water runoff, and increased recharge potential for regional soil groups. These conservation measures will work to increase the vegetative productivity in developing portions of the Region and will contribute to more stable and richer landscaping features.

Social benefits accruing from the control programs can be summarized in terms of decreased health hazard and greater worker productivity; improvements in visual resources and the conservation of important recreation areas; and more livable urban communities for retired citizens, tourists, and the general citizenry.

Economic costs and benefits, while difficult to quantify, will be distributed among various sections of the community. The region as a whole will benefit from the preservation of an attractive and healthful physical environment. This element provides not only an attactive inducement for the location of new industry, but provides a superior living environment which may be equally as important as wage scales in attracting qualified workers to the region. Special sectors of the community, particularly the tourist industry and the housing sector which supplies units for retired military and civilian families, will also benefit substantially from the strict adherence to air quality standards.

Economic costs may be distributed evenly to the region through increased tax assessments, or they may accrue more to particular sectors of the community through higher site costs, and higher costs for certain products. In some cases, cost savings may actually accrue to the private sector: in view of the patchwork pattern of development controls related to grading now existing through local ordinances, Federal insuring requirements, and Air Pollution Control Commission regulations, a comprehensive and streamlined grading program may actually act to reduce development costs in a number of situations. In summary, economic costs, while representing one of the most significant impacts of the grading controls, will not represent an onerous burden for public and private institutions in the region to assume.

FOOTNOTES

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